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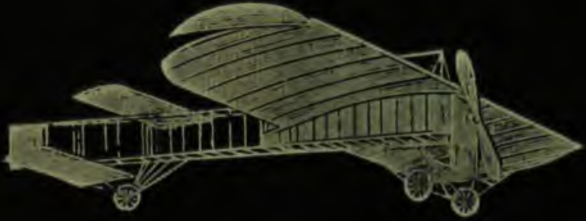
CONQUEST OF THE AIR



ALPHONSE BERGET

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THE CONQUEST OF THE AIR

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THE CONQUEST OF THE AIR

AERONAUTICS
AVIATION

HISTORY : THEORY : PRACTICE

BY

ALPHONSE BERGET
DOCTEUR ÈS SCIENCES. PROFESSEUR A L'INSTITUT OCÉANOGRAPHIQUE
PAST PRESIDENT LA SOCIÉTÉ FRANÇAISE DE NAVIGATION
AÉRIENNE

WITH 83 EXPLANATORY DIAGRAMS
AND 48 PLATES

(New and Revised Edition)

LONDON : WILLIAM HEINEMANN
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1911

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DEDICATED TO

PROFESSOR SILVANUS P. THOMPSON, D.Sc., F.R.S.

PRINCIPAL OF THE CITY AND GUILDS TECHNICAL
COLLEGE; PAST PRESIDENT OF THE
INSTITUTION OF ELECTRICAL
ENGINEERS

At this moment no one can
foresee the influence of Aviation
upon the habits of mankind

PREFACE TO THE FIRST ENGLISH EDITION

THE year 1908 was one of experiment in aerial navigation; 1909 was the year of brilliant achievement.

In 1908 the magnificent experiments of the Wright Brothers excited widespread admiration to a supreme degree. In October of the same year two daring aviators, Farman and Blériot, abandoned their experimenting grounds and set out boldly into the realm of practice. On October 30 Farman accomplished the first "aerial voyage," by travelling from Châlons to Rheims, passing over villages, forests, and hills. The following day Blériot achieved the first "cross-country" journey in a closed circle between Toury and Artenay, making two descents *en route*, and restarting *under his own effort*, without any launching apparatus, finally returning to his starting-point.

The "Conquest of the Air," commenced in 1885 by the first dirigible, *La France*, built by Colonel Renard, is asserted to-day in the new development—aviation.

But now, in 1909, our human birds have excelled. By a remarkable flight, on July 25, Blériot, more fortunate than his rival, Latham, who came to grief off his destination, succeeded in crossing the Channel, thus realising through the atmosphere that *entente cordiale* made between two nations. During August, on the plain of Bethany, near Rheims, in the first "aviation meeting" that had been held, all previous records were beaten. Paulhan, upon a biplane built by Voisin, covered 131 kilometres; Latham, on an *Antoinette* monoplane, traversed 154·500 kilometres without a stop; and Henri Farman, in a triumphant continuous flight, ultimately completed 180 kilometres in 3 hours 4 minutes 56 seconds. In addition to these marvellous exploits, Hubert Latham, striving to secure the victory for height, rose to 156 metres; and Curtiss, the American, won the speed trophy by travelling 30 kilometres in 21 minutes 15 seconds—that is to say, flew at 75 kilometres per hour.

If one recalls the fact that it was during the self-same year, 1909, that two most remarkable voyages were accomplished by dirigible balloons, which have definitely asserted the possibility of their practical application, one will understand that the highway of the atmosphere is now open, and that the "Conquest of the Air" has become an accomplished fact.

Therefore the moment is opportune to explain how this conquest has been effected, to describe the principles of the construction and control of aerial vessels, dirigible balloons, and aviation apparatus. That is my reason for writing this book.

I have written it as lucidly as possible, so that it can be read by all. It has no pretensions to being an "aeronautical encyclopædia," but is rather an "introduction to the study of aeronautics," so that those who read and understand may be able to follow accordingly to advantage the whole progress of the new science as it develops and is described in the Press and the technical treatises.

Thus I hope to have contributed to the diffusion of an interest in the science of the air in the same manner as I hope to have rendered a worthy appreciative tribute to the names of those who were, and are, the victors.

ALPHONSE BERGET

PROFESSOR A L'INSTITUT OCÉANOGRAPHIQUE
DE PARIS
PAST PRESIDENT OF THE SOCIÉTÉ FRANÇAISE
DE NAVIGATION AÉRIENNE

PARIS, *August* 31, 1909

PREFACE TO THE SECOND ENGLISH EDITION

SINCE the first edition of this volume was published eighteen months ago how much has been achieved! What triumphs have been recorded! What striking progress has been accomplished in aerial navigation!

During this time aeroplanes have made voyages in the fullest sense of the word. No longer are such of exceptional moment, and no longer is there necessity to select favourable days and routes. Flights can be made now over fixed courses, and on predetermined dates, as "Le Circuit de l'Est" and the French Military Manœuvres at Picardy demonstrated conclusively. Several officers crossed France through the air from Paris to Pau; Chavez rose nearly to 3000 metres to cross the Alps over the Simplon; Renaux journeyed from Paris to the Puy-de-Dôme; Sommer flew on his aeroplane accompanied by twelve passengers; and the speed of 106 kilometres has been attained.

If the fact is recalled that but ten years ago an attractive prize was offered for a flight over *one kilometre* it is possible to realise what tremendous strides have been made, and how quickly progress has been effected.

And what about dirigibles? Two huge airships built in France crossed the Channel to this country, to be commissioned in the British military service. Wireless telegraphy is installed on these magnificent aerial craft, and this, too, is being perfected more and more every day.

Therefore, we may be proud justly of the progress accomplished and be full of hope for the future.

The sympathetic reception accorded by English readers to the first edition of "The Conquest of the Air" has impressed me deeply, and I take this opportunity to extend them my heartfelt thanks. I trust that the second edition may meet with a success equal to that of the first edition.

ALPHONSE BERGET,

PROFESSOR A L'INSTITUT OCÉANOGRAPHIQUE,
DÉLÉGUÉ PLÉNIPOTENTIARE A LA
CONFÉRENCE INTERNATIONAL DE NAVIGATION
AÉRIENNE

PARIS, *March* 26, 1911

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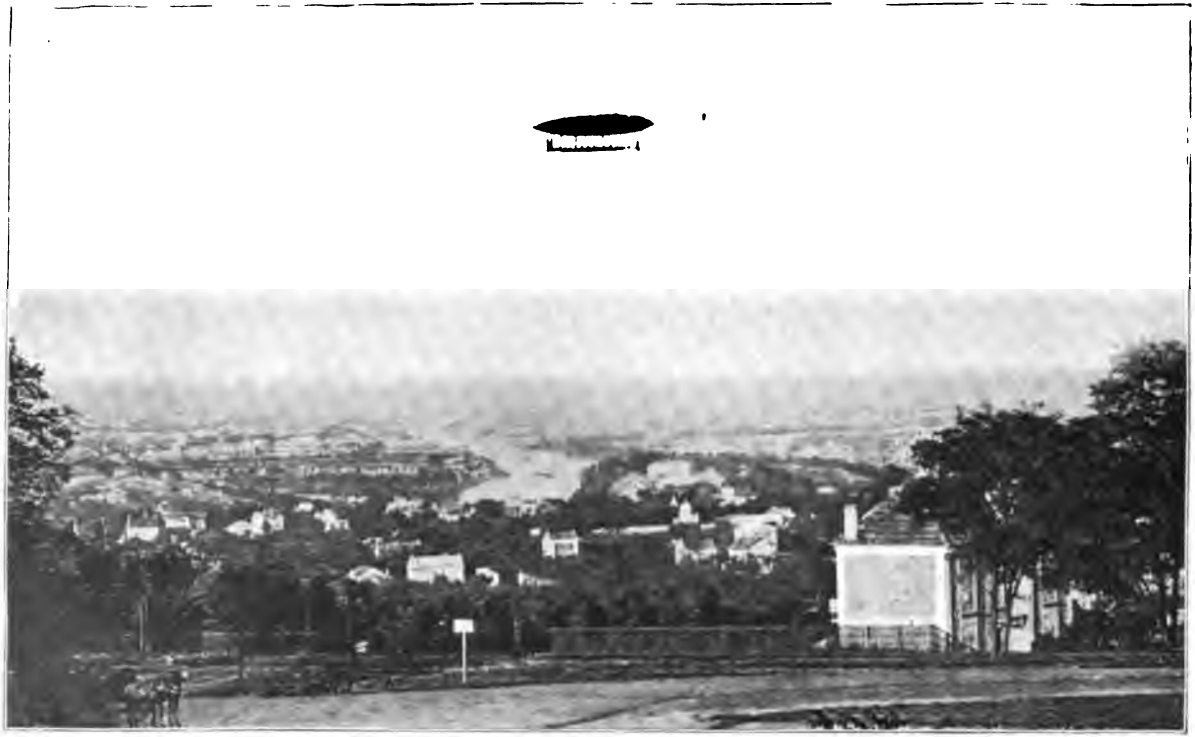

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THE FIRST CIRCULAR FLIGHT BY DIRIGIBLE MADE TWENTY-FIVE YEARS AGO. "LA FRANCE" PASSING OVER PARIS, SEPTEMBER 25, 1885

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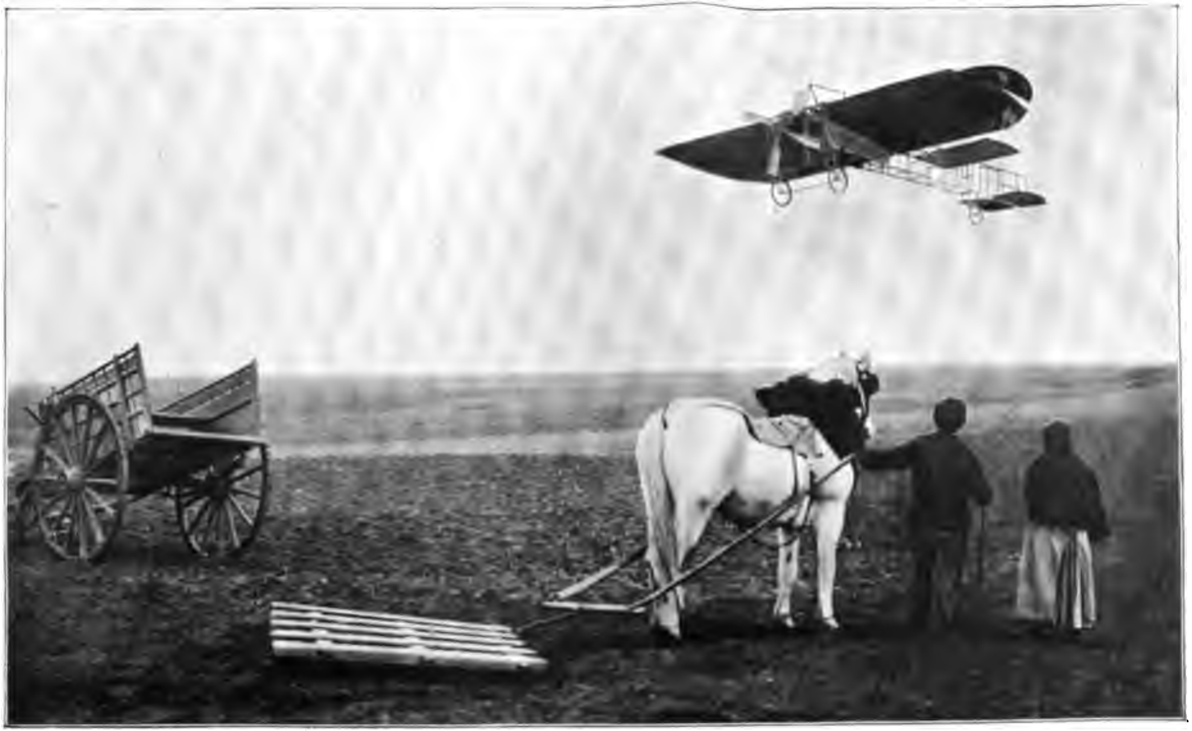

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THE FIRST ROUND JOURNEY BY A "HEAVIER THAN AIR" MACHINE. THE FLIGHT OF THE "BLÉRIOT" AEROPLANE FROM TOURY TO ARTENAY AND BACK WITH INTERMEDIATE DESCENTS, OCTOBER 31, 1908

INTRODUCTION

AERONAUTICS is the art of sustaining and directing oneself in the atmosphere, without coming into contact with the earth or the water on its surface.

The solution of this problem has been sought for ages by men, ambitious to imitate the birds. It was solved partially in 1783, when the Brothers Montgolfier, for the first time, succeeded in raising and sustaining in the air a heavy body capable of carrying passengers. This discovery, the principle of which differs from that governing the flight of birds, was of the utmost importance. It had the merit, not only of showing that the atmosphere was far from being a realm wholly forbidden to man, but also, by providing him with the means for sustentation therein, allowing him to hope that some day he might be able to steer his course wherever he desired.

But Montgolfier's invention did not constitute aerial navigation. The "aerostat," appropriately christened, was inert in the midst of the atmosphere. It was to the airship of man's dreams what the buoy is to the ship, that is, a floating object, the toy of the fluid in which it floats. Three-quarters of a century passed in vain attempts to steer these, until the Frenchman Giffard first showed by a conclusive experiment the feasibility of deviating balloons, a possibility which was achieved triumphantly by Colonel Renard twenty-[illegible] years ago—in 1884.

Hence, a balloon floating in the air by virtue of the principle formulated by Archimedes, because its weight is less

[illegible]

Photo, Rol

"BLERIOT" AEROPLANE FROM TOURY

[illegible]

INTRODUCTION

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Therefore, a balloon floating in the air by virtue of the principle formulated by Archimedes, because its weight is less than that of the air it displaces, can now be steered successfully. This first solution of aerial navigation had the merit of distinct novelty. Nature has nothing comparable to show us. It differs as much from the flight of birds as the movement of a railway train is opposed to that of the most agile of our quadrupeds.

But the bird's example persistently incited the human brain to seek a further solution. The problem was to rise into the air mechanically, without the cumbersome intermediary of a volume of light gas enclosed in an impermeable envelope—in a word, to navigate the air in the manner of the bird with an apparatus *heavier than air*.

The first essays were made a long time ago, but it was not until 1895 that the solution already presaged assumed tangibility. Now at last aerial navigation without an aerostat, mechanical sustentation, *aviation*, in short, is an accomplished fact; its practical application is merely a question of minor improvements.

Thus there are two quite distinct forms of aerial navigation—by *dirigible balloon* and *aviation* respectively. This affords us a natural division for this book, in the first part of which we shall deal with dirigible balloons.

PART I
DIRIGIBLE BALLOONS

CHAPTER I
PRINCIPLES

HOW THE AERIAL VESSEL FLOATS AND MOVES: WHY DIRIGIBILITY MUST DEPEND ON A MOTOR AND A PROPELLER: A COMPARISON BETWEEN MARINE AND AERIAL NAVIGATION

THE PRINCIPLE OF ARCHIMEDES

A DIRIGIBLE balloon is an apparatus which is supported in the air by making use of the *pressure* exercised by this on all bodies plunged therein. By the aid of a *propeller* revolved by a *motor*, it can and must move in this element at the will of the aeronaut.

I can explain the fundamental principle of aerostatics in a very few words.

It was discovered by Archimedes, and formulated as follows:

Every body plunged into a fluid is subjected by this fluid to a "pressure" from below to above, which is equal to the weight of the fluid displaced by that body.

It is by virtue of this principle that ships float on, and fish swim in, water. When a body, the exterior volume of which is a cubic metre, is plunged into water, this body displaces a cubic metre of water, or, in other words, 1000 litres. Now 1000 litres of water weigh 1000 kilogrammes. Three possibilities may then arise: the weight of the body immersed may be less than 1000 kilogrammes, when it will rise and float on the surface; or it may be exactly 1000 kilogrammes, in which case it will remain in equilibrium in the water at a certain level; or, finally, it may weigh more than 1000 kilogrammes, and then it will sink to the bottom.

These three factors are realised by fish, which at will are able to rise to the surface, to suspend themselves in the water, and to sink to the bottom. To carry out these distinct movements they vary their specific gravity by the help of their natatory gland, a bag containing air which they can dilate or compress as they please. We shall see later, in dealing with dirigible balloons, a similar organ in the "air-ballonnet."

HOW DOES A DIRIGIBLE BALLOON RISE? THE ASCENDING EFFORT

The principle being laid down, we may make use thereof to raise an object into the atmosphere; we have only to produce a body, the total weight of which shall be less than that of the volume of air it displaces.

Now the weight of the air is known: a cubic metre thereof weighs 1·293 kilogrammes, that is to say, about 1300 grammes, when the temperature is at zero and the barometer indicates 760 millimetres. On the other hand, there are "light" gases, such as coal gas and hydrogen. A cubic metre of the former at zero, weighs about 500 grammes, while a cubic metre of hydrogen, under the same conditions, weighs only 110 grammes.

Let us take this latter, the most suitable for the object we have in view. Let us make a huge vessel of some flexible and impermeable material—a "balloon"—and let us fill this "envelope" with hydrogen gas. Let us suppose that the interior volume of this receptacle is 1000 cubic metres; when filled with hydrogen it will weigh 110 kilogrammes; but the 1000 cubic metres of air that it will displace will weigh 1293 kilogrammes.

The difference, *i.e.*, 1183 kilogrammes, will be the vertical upward *pressure* exercised on the vessel according to Archimedes' principle. The envelope by being inflated with hydrogen therefore will be capable of lifting 1183 kilogrammes; that is to say, 1 kilogramme 183 grammes per cubic metre. A balloon thus constructed is called an *aerostat.* The point where the pressure which supports it is exerted is called the *centre of pressure*, and its position coincides more or less with that of the centre of gravity of the inflated envelope.

If, then, the weight of the envelope itself, plus the weight of a support to carry the motor and propeller, and the weight of the aeronauts does not exceed 1180 kilogrammes, the apparatus will rise. This difference between the vessel's weight and its lifting power is called its *ascensional effort.* If the total weight of the envelope and of the system it supports exceeds 1180 kilogrammes, the apparatus will remain on the ground.

If, instead of inflating our envelope with hydrogen, we had used coal gas, it would only have been able to raise 690 kilogrammes instead of 1180; obviously therefore, there is an advantage in using hydrogen.

The very existence of the ascensional effort produced by the pressure of the surrounding air provides the aeronaut with simple means to make his balloon rise or sink at will. If he wishes to rise, he has only to throw out of his car a portion of the weight it contains; *ballast*, in the form of bags of sand, is always carried for this purpose. If, on the other hand, he wishes to descend, he has only to diminish the ascensional effort of the aerostat. This is done by allowing a certain quantity of the light gas it contains to escape through a *valve*, which can be opened and closed at will. The difference between the weight of the air and the weight of the gas is then diminished; that is to say, the pressure is reduced and the balloon descends.

THE BALLOON ENVELOPE, RIGGING AND CAR

The essential device for sustaining the balloon in the air is therefore the *envelope*, which we shall inflate with a light gas; it must further fulfil the conditions of *lightness*, *strength*, and *impermeability*.

It must be *light*, because its weight forms part of the total weight the balloon must lift, and which must be deducted from the load which the apparatus will be able to carry. It must be *strong*, for it will have to withstand the strain from the gas with which it is filled, and also the stresses exercised on its various parts by the weight of the objects and passengers on the one, and by the shocks and vibrations of the motor on the other, hand. It must be *impermeable*, that is to say, must not allow the gas it contains to ooze through its pores, for it is this gas which, owing to its lightness, enables the balloon to rise into the air, and if any portion thereof were to escape, the ascensional effort would be diminished at once.

The material now used almost exclusively for the construction of dirigible balloons is a composite fabric, consisting of two layers of cotton, between which is inserted a thin layer of india-rubber, the tenth of a millimetre in thickness. This material is unvarnished. It weighs 300 grammes per square metre; can withstand a strain of 1250 grammes per metre; and has an equal power of resistance in the direction of warp and woof. The manufacture of this material is carried on in France and Germany; it has become a regular off-shoot of the rubber industry.

Light as our envelope is, it has, nevertheless, an appreciable weight, to which we must add that of the "rigging"—*i.e.*, the suspension ropes by which the aerostat supports the *car*, that light, yet solid, receptacle which contains the motor and the passengers, and which also carries the *propeller*;—the mechanism which utilises the resistance of the air to drive the dirigible balloon forward.

We may note in passing that an aerostat furnished with a motor is generally called an "airship."

IT IS ONLY POSSIBLE TO STEER A BALLOON BY THE AID OF A MOTOR

Why was it so long before it was possible to steer a balloon when, so far back as 1783, man, applying the principle formulated by Archimedes, had been able to lift himself into the air? It was not, indeed, until 1884 that the first *circular* flight was accomplished by Colonel Renard with a balloon which after all deserved the title of *dirigible*. Why was this?

Because, before it is possible to "steer" a body floating in a fluid, it is absolutely essential that this body should possess an *independent speed* to permit it to move in this fluid of its own accord. I can illustrate this point by a very simple and familiar comparison.

Let us take a boat which has a rudder at the stern and is propelled by a pair of oars. A rower, manipulating these, imparts a certain speed to the boat. So long as this speed is appreciable, the rudder acts efficiently, and the steersman only has to move it to the right or to the left to alter the course of the vessel. But let the rower rest on his oars, and the boat, deprived of speed, will float "like a buoy," and it will be useless for the helmsman to work the rudder, because the latter will have no effect upon the boat, which will be the sport of the water on which it floats. Thus in order to steer the boat, we must propel it.

In the same way we must "propel" an aerostat if we want to "steer" it. But to propel it we must have a motor, and any motor is necessarily heavy. Let us now inquire into the respective weights of the motors it would be possible to use.

In the first place, there is the "human motor," that is to say, the muscular energy of the aeronauts in the car. It is hardly necessary to say that this was the first motor to be taken into account in the earliest days of aerostation, for there was none other known at that period. But though such a dream was then possible, it is so no longer, for to-day we have more precise data resulting from mechanical experiments which have established the weight-conditions of each class of motors.

The practical unit of energy is steam horse-power, that is to say, a force capable of raising 75 kilogrammes one metre from the ground in one second. This power is very much greater than that of the animal horse. A man represents but a fraction thereof. Now mechanicians have established by experiment, independently of all theory, that the weight of the steam horse-power translated into human muscular power, is about 1000 kilogrammes; in other words, it takes 1000 kilogrammes of men to produce an effort equal to that of the steam horse! Therefore it was futile, obviously, to attempt to steer balloons by utilising the muscular power of the few aeronauts who controlled them.

In the early days of steam power, motors were of considerable weight. The engine of the *Sphinx*, the first steamship in the French Navy, weighed more than 1000 kilogrammes per horse-power, and even thirty years ago steam motors weighed some 100 kilogrammes per horse-power. Hence the first steam engines were no more suitable for the propulsion of aerostats than human effort, to say nothing of the danger of installing a boiler heated by coal beneath an envelope inflated with hydrogen, an eminently inflammable gas.

Nevertheless, steam was the power used with the first motor for a balloon. Its application was essayed in 1852 by the engineer, Henry Giffard. Instead of using the steam motors already in existence, he had built one of three horse-power expressly for his experiment; he succeeded in reducing the weight per horse-power to 53 kilogrammes; this was a remarkable achievement at the time and an enterprise of extraordinary audacity, taking its dangers into account. But the steam engine was abandoned very soon, owing to the risk of fire, and aeronauts adopted the electric motor, which, from 1880, was regarded as the aeronautical motor of the future. Colonel Renard succeeded in obtaining an electric motor of 8 horse-power, weighing only 40 kilogrammes per horse-power, and capable of great endurance; this rendered *real* aerial navigation a possibility, which he had the honour to accomplish first in 1885.

But about 1890 a new engine made its appearance; rude and clumsy at first, it was improved and perfected very soon. Thanks to this invention, a new industry was born—the automobile—which has revolutionised all our habits. The engine was the "explosion motor."

Power for power, the explosion motor is the lightest known prime mover. To-day mechanicians have succeeded in perfecting motors especially designed for aviation of the almost incredible weight of 2 kilogrammes per horse-power. Moreover, its action has been perfected; it can start in an instant without preliminary preparation. The volume has been reduced proportionately to the weight, so the engine is not cumbersome. It is due to this development that aeronautics have become what we see, and that aviation has been made possible in its turn. The explosion motor is the *only* one now used in aerial navigation.

WEIGHT PER HORSE-POWER, AND PER HORSE-POWER HOUR

If we consider a machine able to yield 100 horse-power for a weight of 1000 kilogrammes, we say that the "weight per horse-power" is 10 kilogrammes. But such data is insufficient for the aeronaut in working out his constructional designs.

We have not only to lift our vessel, but to use it, to make it travel, and for this purpose we require a combustible, which in our particular case is petrol. Then we must have water to cool the motor, oil to grease its mechanism, and other accessories necessary for its operation. In a word, if our 100 horse-power engine consumes 1 kilogramme of various materials per horse-power, it will use 100 kilogrammes of provisions per hour. If we want to make it go for ten hours, it will require 1000 kilogrammes of necessaries, the weight of which must be added to that of the machine itself.

Thus, in the example we have taken, we shall have 1000 kilogrammes, the net weight of the engine, and 1000 kilogrammes of fuel &c., to enable it to run for ten hours, making a total of 2000 kilogrammes. But for these 2000 kilogrammes we shall get 100 horse-power for ten hours—that is, 1000 horse-power hours. The weight per horse-power hour is, obtained therefore, by dividing 2000 by 1000; which represents 2 kilogrammes.

It is essential that we should not confound these two terms; the weight per horse-power hour depends on a proper use of the combustible by the engine, whereas the weight per horse-power depends solely on the construction of the engine. As Colonel Renard pointed out, it is possible to have the same number of kilogrammes for the weight per horse-power hour with a light engine that consumes a great deal, as with a heavy engine that consumes very little; but with too heavy an engine the balloon perhaps would not rise at all; and the first duty of a balloon, even of a dirigible, is to rise into the air: *primum vivere, deinde philosophari*, said the philosophers.

To conclude what we have been saying, we may lay down this principle: the motor above all things, should be as light as possible; that is to say, the point of primary importance is to keep down the weight per horse-power. As to the diminution of the horse-power hour, this would merely enable us to prolong the duration of the voyage, or, to use a phrase proper to naval warfare, to extend the "radius of action" of the airship.

MARINE AND AERIAL NAVIGATION : THE DIRIGIBLE, THE STEAMSHIP, AND THE SUBMARINE

The airship has been compared often to the steamship; the aerial ocean to the marine ocean. Is this a legitimate comparison? We will examine this question briefly.

First we must note the essential and absolute difference between an airship and a steamboat. The latter floats upon an element of great density, the water, in which its propellers find an appreciable fulcrum, by virtue of its great resistance: but a part of its hull is submerged, and it is upon this portion only that [the resistance which the surrounding liquid offers to the advance of the vessel is exercised. The balloon, on the other hand, is immersed completely in the liquid wherein it is sustained by the vertical thrust. The latter varies constantly owing to the weight of a gas, the thermal expansion of which is very great, fluctuating in accordance with the slightest vicissitudes of temperature or of barometric pressure, whereas the "hydrostatic pressure" which causes the ship to float upon the water does not vary appreciably when the temperature changes.

But no floating vehicle, be it balloon or vessel, is ever required to float in a perfectly immobile element. The ocean is agitated by marine currents such as the Gulf Stream, which circulates across the Atlantic, or the tidal currents at certain places around our coasts. On the other hand, the atmosphere is in perpetual motion under the action of the "winds," which are aerial currents. But there is a striking difference between these two kinds of currents. Whereas the most rapid of marine currents, such as the Raz de Sein on the Brittany coast and the Raz Blanchard do not exceed a speed of 9 knots (16·500 km. per hour), the aerial currents have often very considerable velocities. Directly the wind "freshens," as sailors say, its speed is increased very soon from 10 to 15 metres a second, that is, from 36 to 56 kilometres an hour. A steamship driven at high speed—in the most modern types 20, 25, and even 30 knots—will overcome the ocean currents very soon, the speed of which need only be deducted from that of the ship; whereas the dirigible balloons are compelled to struggle against currents of air the violence of which condemn it to immobility—or to retreat.

In short, the ship and the dirigible balloon are not comparable. The only exact parallel of this kind which we could draw is that of the airship and the submarine, which also is immersed completely in its supporting fluid. Still the advantage is on the side of the submarine, which never has to overcome the rapid currents with which its aerial counterpart has to contend. A juster comparison might be made between a dirigible balloon and a submarine which has to advance, not against a current, but against a torrent.

We can now see how difficult a problem is the propulsion and steering of aerostats and we can understand why it has taken a century to discover how to guide the machine which the brothers Montgolfier launched into the air for the first time in 1783.

CHAPTER II

THE RESISTANCE OF THE AIR

OBSTACLES OPPOSED TO THE ADVANCE OF THE AIRSHIP: THE MOST ADVANTAGEOUS CONDITIONS OF SHAPE AND DIMENSIONS FOR THE ENVELOPE: INDEFORMABILITY: THE EQUILIBRIUM AND STABILITY OF AIRSHIPS

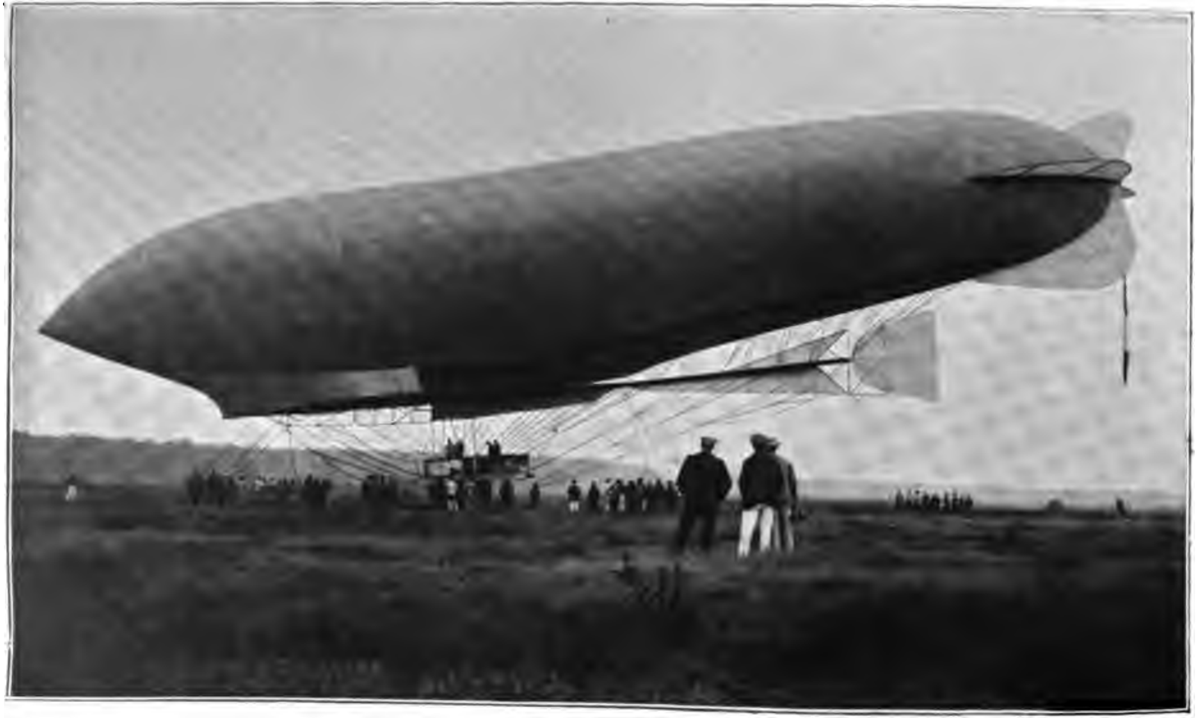
THE RESISTANCE OF THE AIR

THEREFORE we are going to take an aerostat, and provide it with a motor to give it an "independent speed" which will ensure its propulsion, and consequently, its direction.

But when we thus propel our aerostat, it will experience a resistance to its forward movement from the surrounding atmosphere. Whenever we attempt to displace a body of any kind in a material fluid—for instance, if we try to move a board which we hold in our hand in the water—we feel a resistance to the movement we are trying to produce. This resistance does not depend upon the volume or the total mass of the body displaced, for we feel that it varies according as to whether we hold the board flat or edgewise. We also note that the resistance is greater, if, all other conditions being equal, we try to move it faster.

Physicists on the one, and engineers on the other, hand, have attempted to establish the laws of this "air-resistance" both by calculation and experiment. They have arrived at the following conclusion, which is correct in the main, but merely approximate if we demand precision: "the resistance offered by the air to a surface element which is moving on a line perpendicular to its plane is proportional to the extent of this surface, to the square of the speed which animates it, and to a numerical *co-efficient*, the mean value of which is

PLATE III

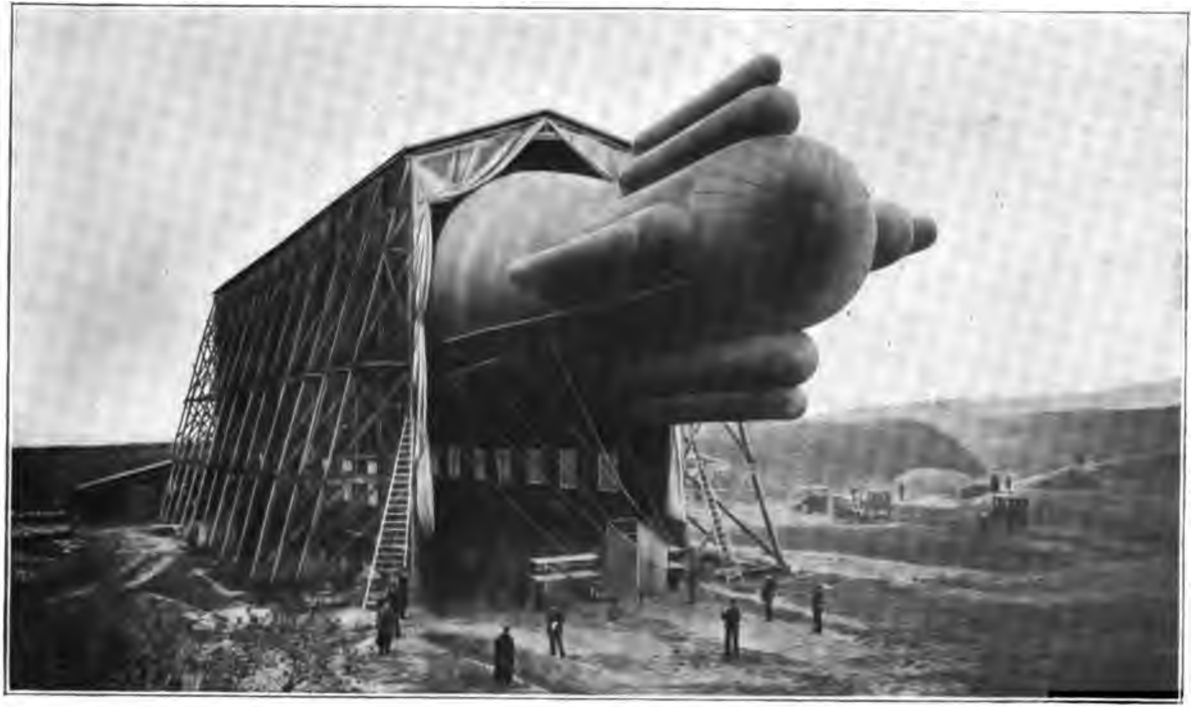


Photo, Branger.

THE DIRIGIBLE BALLOON "RÉPUBLIQUE"

This vessel represents the "semi-rigid" type. The envelope is flexible, and beneath is the keel from which the car is suspended. The stern empennage comprises four fins or planes

PLATE IV



Photo, Branger

THE "VILLE-DE-PARIS" IN ITS SHED

The empennage comprises cylindrical ballonets

0·125. Thus if the surface of the moving element is measured in square metres, and if the speed is expressed in metres per second, the result represents the resistance in kilogrammes (Fig. 1).[1]

For instance, let us consider a board, having a superficies of 4 square metres moving normally to its plane at a speed of 10 metres per second; the resistance, in kilogrammes, will be obtained by multiplying the area, 4, by the square of the speed, that is to say by 10 × 10, or 100, and by multiplying the sum by the *co-efficient* 0·125 (4 × 100 × 0·125 = 50 kilogrammes). If the speed of movement be doubled, the resistance of the air will be quadrupled; it would become nine times greater if the resistance were tripled—and so on.

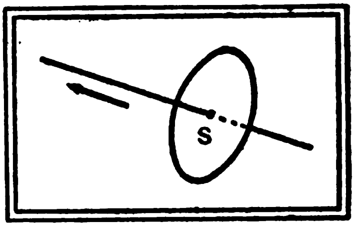


FIG. 1. Resistance of the air upon a surface moving normally

When the moving body is faced with a "prow," that is, a surface having tapering sides, which separate the molecules of air without striking them sharply as would a flat surface, the resistance is diminished. Thus, if we take the panel of Fig. 1, but cause it to be shaped so as to divide and thrust aside the molecules of air, as would be the case if we made use of the hemisphere or the cone (Fig. 2) with the base of the same superficies as the panel, the resistance of the air to the speed

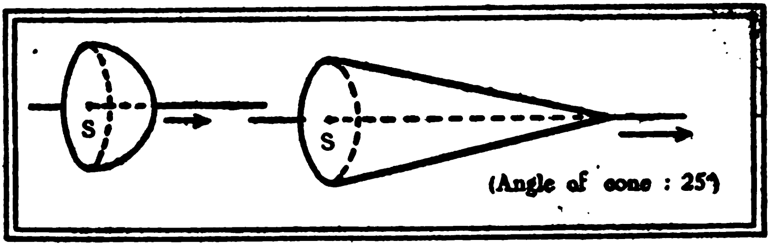


FIG. 2. Influence of front shape

The two models shown in the illustration, and travelling from left to right, are fitted with a "prow," one spherical, and the other conical, to force aside the masses of air more easily.

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[1] The reader who wishes to know the *formula* of the resistance of the air, is referred to the Appendix to this book.

of 10 metres per second, which was 50 kilogrammes for the flat panel moving perpendicularly to its plane, will be but 25 kilogrammes for the hemisphere, and only 9 kilogrammes for the acute-angled cone.

Experience has shown that not only is the shape of the "bow" of the moving body important, but so is that of its "stern," or "poop." The profile of the latter may permit either an easy reunion of the molecules of air separated by the prow which glide along the sides to rejoin each other, or, on the other hand, its abrupt formation may cause the molecules separated by the prow to re-unite tumultuously, clashing one with another and producing eddies behind the moving bodies.

THE SHAPE OF DIRIGIBLE BALLOONS : SPINDLE, FISH, AND CYLINDER

The points we have just considered determine the shape of the envelope for a dirigible balloon.

There can be no question of attempting to propel a spherical balloon. The surface on which the resistance of the air would be exercised during the advance would be enormous. With an equal volume of envelope, it is necessary to select lines that present as small a surface as possible to the air as it advances, while preserving the utmost lifting power. This condition is fulfilled by giving the envelope an elongated longitudinal shape.

But what should be this elongated form? Should it be that of a symmetrical spindle, an ovoid body, and in this event, should it advance with the larger or smaller end foremost? Or should it be cylindrical?

The first attempts, those of Giffard in 1852, of Dupuy de Lôme in 1872, and of Tissandier in 1884, were made with "fusiform" (spindle-shaped) balloons; in other words, their shape, equally pointed at either end, was symmetrical in relation to the central plan (Fig. 3). But all this was changed when that man of genius, indisputably the father of aerial navigation, appeared, Colonel Charles Renard, whose early death in 1905 was an irreparable loss to science and to France.

Renard demonstrated by his calculations that the most advantageous lines are those of a dissymmetrical fish (B), with the largest end at the front. So long ago as the beginning of the nineteenth century, Marey-Monge had presaged the necessity of adopting this form if an attempt should be made to propel aerostats: "They must have the head of a cod and the tail of a mackerel" was his dictum.

This, indeed, is the shape of all birds and of all swiftly moving fishes—whales, cachalots, and porpoises. At present all dirigible balloons which have proved really capable of progression are *all* constructed on the lines worked out by Renard.

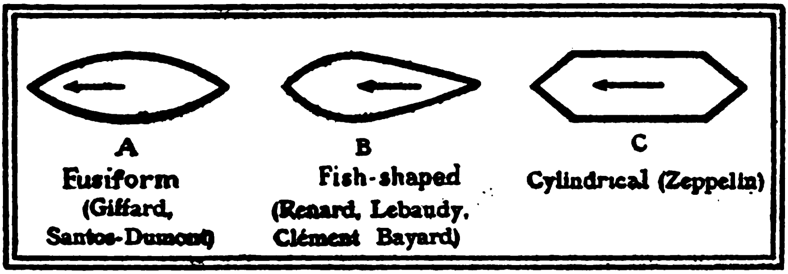


FIG. 3. Different shapes of dirigibles

We must now point out that if the conditions of progression and of the resistance of the air are to be normal, *the balloon must preserve its shape* during its course, either ascending or descending. We shall see later how this condition is fulfilled by the "air ballonnet."

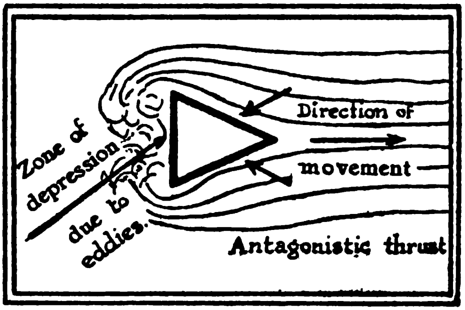


FIG. 4. Eddying action resulting from flat shape of stern

The stern eddies produce a partial vacuum to which the travelling body strains to move, thus setting up a force opposed to the direction of travel, and which consequently retards forward movement.

As to the cylindrical form (C), adopted in Germany by Count Zeppelin, it seems less advantageous. The molecules of air thrust apart by the point in front exercise an exaggerated friction on the sides before they re-unite, thus retarding the progress of the airship. The other German aeronauts therefore are returning gradually to the pisciform shape.

In any case, the pointed stern is indispensable, for without it there would be an eddy of the molecules of air, and consequently a partial vacuum which would cause antagonistic thrust at the prow. This pressure, acting against the forward movement, would retard the speed of the airship (Fig. 4). Therefore it is necessary at all costs to avoid such by tapering the rear end of the balloon.

RESULT OF AIR RESISTANCE: ADVANTAGE OF BALLOONS OF LARGE CAPACITY, STRENGTH AND SPEED

The resistance of the air to the movement being proportionate to the square of the speed, leads us to a most important conclusion. This is, that balloons of large size have an advantage over those of smaller dimensions. Let me explain.

To start with a clear idea, let us consider an airship in the shape of an oblong box with a square base, the latter being, for instance, 1 metre wide and deep, by 5 metres long. Its volume will be five cubic metres, and its ascensional effort, taking this at 1 kilogramme per cubic metre, will be 5 kilogrammes. This balloon, if inflated with hydrogen, will lift, in round numbers, a motor the power of which will be limited by this weight of 5 kilogrammes; and if we suppose that a motor weighing exactly 5 kilogrammes per horse-power has been constructed, the motor this balloon can lift will be of one horse-power.

Having demonstrated this, let us construct a second airship, a replica of the first, also inflated with hydrogen, but with all the dimensions doubled; that is to say, having a squared base of 2 metres, by a length of 10 metres instead of 5. The volume of this balloon will not be double that of the first, it will be $2 \times 2 \times 10 = 40$ cubic metres; that is, eight times larger, while its surface of resistance to progression will be that of its base, *i.e.*, 4 square metres.

Thus, as we have doubled all the dimensions, the resistance of the air will be *four* times greater, whereas the volume, otherwise the lifting power, will be *eight* times as much.

Now, with an ascensional effort eight times greater, it will be possible to lift a motor eight times more powerful, and even more, because the weight per horse power diminishes in proportion as the power of the motor increases. Therefore, the balloon, the dimensions of which have been doubled will have a 8 horse-power motor at least to meet an air resistance bearing upon four square metres; that is to say, two horse-power per square metre of the transverse section, whereas the balloon of half this size will have only a 1 horse-power per square metre of the section. The advantage is consequently all on the side of large balloons, and aeronauts who wish to undertake important journeys, and to carry large stores of fuel, and numerous passengers, will find it profitable to construct dirigible balloons of large dimensions, The largest dirigible balloon yet constructed for such a purpose is the *Zeppelin*, of 18,000 cubic metres, whilst the smallest is the Santos Dumont No. 1, which gauged but 180 cubic metres. True its only passenger, M. Santos Dumont, weighed only 52 kilogrammes, and that the whole car weighed but 10 kilogrammes!

To sum up, we may say that the volume, on which the power of the motor that can be carried depends, varies according to the cubic dimensions of the airship, whereas its surface, on which the resistance offered by the air to its progress depends, varies only according to the square.

Finally, it is necessary to point out *that the power necessary to communicate increasing speeds to the same airship increases proportionately to the cube of the speed.* This law has been demonstrated by calculation and verified by experience. It is of vital importance, for it leads to various conclusions of the utmost moment. Thus, to double the speed of a dirigible balloon, we must give it a motor power not *twice*, but *eight* times greater (8 is the cube of 2; $8 = 2 \times 2 \times 2$).

So if we take into consideration a modern dirigible, say the *Clément Bayard*, having a speed of 45 kilometres an hour from motors of 100 horse-power, in order to double that speed it would be necessary to fit the same airship with motors of 800 *horse-power*. It is a repetition of the naval constructor's wail—speed costs money.

We see therefore that great care is necessary in calculating the elements of a dirigible balloon, when it is destined to undertake journeys of any length.

THE "RADIUS OF ACTION" OF AN AIRSHIP

But a dirigible balloon must not be a mere object of scientific curiosity, or a vehicle of sport. It must have a useful application; it must be able to accomplish journeys. The longer the duration of the latter, the greater is the utility of the apparatus. Therefore it is necessary, first and foremost, to ensure long-sustained flight by the dirigible.

Here the speed question plays a very important part, as does also that of the motor power it is necessary to apply to the airship to give it the desired speed. This power, as we have just seen, is proportional to the *cube* of the speed. And this must be taken into account if travelling velocity is not the sole desideratum, and if the *total* distance the aerial vessel can travel is also an important factor.

Let us consider a balloon of 3000 cubic metres, travelling at the rate of 60 kilometres an hour, with two engines of 60 horse-power each. These motors consume a total quantity of 60 kilogrammes of petrol an hour. The balloon, carrying six passengers, can take 600 kilogrammes of petrol, which renders a ten-hour journey possible. If we take into consideration that it has to return to its starting-point, its pilot has only five hours' outward travel at his disposal, or, reckoning 60 kilometres to the hour, 300 kilometres. We should say under these conditions that the *radius of action of this dirigible balloon is* 300 *kilometres.*

Let us now suppose that only one of the motors is working. The propelling power then will be only 60 horse-power; the speed will be divided by the cube root of 2, that is, in round numbers, 1·25; it will therefore be 48 kilometres an hour. But the single motor does not consume more than 30 kilogrammes of petrol, and there are 600 kilogrammes on board. Therefore the airship will *have twenty hours of travel* before it, instead of ten; that is, ten outward and ten return. Consequently it will be able to travel 10 times 48 kilometres and still have the means of returning to its starting-point. We should say therefore that *under these altered conditions, the radius of action of the dirigible is* 480 *kilometres.*

Thus, by demanding a speed of 48 kilometres only per hour instead of 60, we extend the *radius of action* of the same dirigible from 300 to 480 kilometres. Hence we have increased it very considerably.

This shows us how important is the consideration of the radius of action, especially in the application of aerial navigation to military or geographical operations. One thing should be clearly understood: *speed is costly* on an airship as it is on a transatlantic liner. To double it, the motor power must be multiplied by eight; the balloon therefore must carry eight times more fuel; whereas, by diminishing the motor-power by one-half, the speed is only reduced by one-fifth. When, therefore, airships seek to perform long aerial voyages, the problem confronting them will be, how to reconcile the minimum speed enabling them to make way effectually against the prevailing winds, with a reduction of the motor power, which by diminishing the amount of fuel consumed, will enable the store of petrol to hold out sufficiently to reach the most distant points! The wisest solution obviously would be to furnish the dirigible balloon with two independent motors. When a "special effort" was required, the two engines could be used; but under favourable atmospheric conditions, the travellers would be content with the propulsion furnished by a single engine. Though the speed would be diminished somewhat, it would be possible to travel a good deal farther through the air.

All we have said above concerning a dirigible's "radius of action" applies of course to aeroplanes, for which this consideration is also of the greatest importance.

CONDITIONS OF EQUILIBRIUM OF DIRIGIBLES

The first condition to be fulfilled by our dirigible balloon, whether stationary or in motion, is that it should always be "in equilibrium."

When stationary, the airship should always maintain such a position that the geometrical axis of the solid body formed by its envelope is horizontal. Now when a dirigible balloon is suspended motionless in calm air, it is subjected to the action of two forces; one is its *weight*, P (Fig. 5), which is applied to the centre of gravity of the system C formed by the envelope and all its supports; the other is the *thrust* of the air, applied to a point B called the *centre of thrust*. If the envelope contained only its inflating gas, and had neither car nor cargo to carry, and even if the weight of this envelope were negligible, the centre of thrust and the centre of gravity would coincide. But the addition of the weights that the envelope has to lift into the atmosphere causes this result: these two forces are not a continuation of one another.

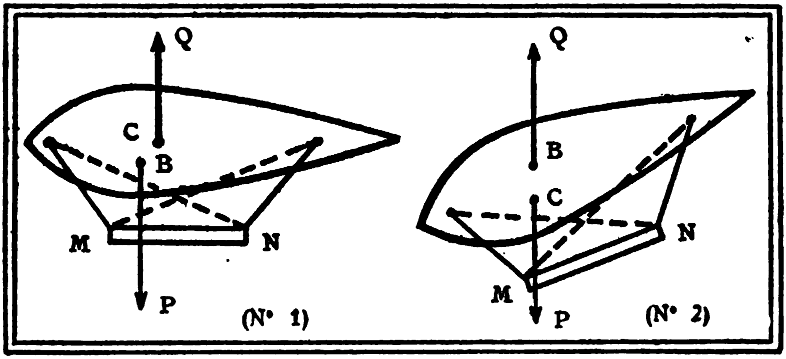


Fig. 5. Triangular suspension connection (indeformable)

The car always maintains its position relative to the balloon irrespective of the tilting of the airship

As they must necessarily be equal if the balloon neither ascends nor descends, it follows that they will make the balloon turn until they are a continuation of one another, and our airship will then take the position indicated by Fig. 5 (No. 2).

Now this inclined position would be incompatible with rapid speed, inasmuch as it would increase, in the travelling direction, the extent of the area exposed to the resistance of the air. Moreover, the air gliding over the greater surface, arising from inclination, and attacking the latter obliquely, would tend to drive the airship downwards. We shall see later how the aeroplane is based precisely upon this principle.

Hence to avoid this inclined position, the weight must be distributed properly along the car from MN, in such a manner that, when the balloon is horizontal, the two forces, pressure BQ and weight CP, are upon the same vertical line. Then

" static equilibrium " will be ensured. We see therefore that the connections between the car and the envelope must never vary, though at the same time they must be allowed a certain flexibility, which is indispensable to aerial navigation. We shall return to this question when we deal with longitudinal stability.

But this is not all; the balloon, as it advances under the combined action of its motor, rudder and the resistance of the air, must preserve a general stability. It must remain perceptibly horizontal, and must not execute violent or extensive movements, either from fore to aft, or from right to left; in other words, there must be neither " pitching " nor " rolling."

Every one knows the general methods of aeronauts with spherical non-dirigible balloons. To ascend, they diminish the total weight of their balloon by throwing out ballast, that is, part of a supplementary weight, comprising bags of sand, which they carry with them. When, on the other hand, they want to descend, as they have no means of increasing their weight, they diminish the thrust of the air on the balloon by permitting some of the light gas in the envelope (the specific lightness of which constitutes the lifting power of the balloon) to escape through a valve. This ascensional effort diminishes in proportion to the amount of gas allowed to escape. The aeronaut therefore is able to ascend or descend at will by the dual means of ballast and valve.

But this simple method cannot be applied to the operation of a dirigible balloon. Dynamic equilibrium, that is to say the equilibrium of the airship in motion, must take into account not only its weight and the sustaining pressure of the air, but also the resistance of the air brought to bear upon its envelope, which resistance depends on the dimensions and the *shape* of that envelope; in calculations, this shape is assumed to be invariable. Now what will happen if we allow a portion of the gas enclosed in the envelope to escape? When the balloon descends from the atmospheric stratum from which the aeronaut wishes to approach the earth, it will find itself in masses of air, the pressure of which increases as it nears the ground. This may be understood easily, since the lower strata bears the weight of the upper strata. The confined gas, now insufficient to fill the balloon as a certain portion has been allowed to escape, will contract; the balloon, no longer full, will become flaccid, and will lose its original shape. Consequently the centre of resistance of the air will have changed, as well as the centre of thrust, and the initial conditions will no longer prevail. As these conditions were used as the basis of calculations dealing with the equilibrium of the airship, that equilibrium can be maintained no longer.

THE AIR BALLONNET : RIGID BALLOONS

All these inconveniences are obviated by an ingenious contrivance, the idea of which originated with General Meusnier, who formulated it in 1784, only a year after the brilliant experiments of the Montgolfier brothers. As with all remarkable developments evolved prematurely, General Meusnier's idea was forgotten, and it was not until 1872 that the famous naval engineer, Dupuy de Lôme, the inventor of the ironclad, resuscitated it in connection with his attempts to make balloons dirigible.

We have seen above that it is absolutely essential to keep the balloon always perfectly inflated; on the other hand, in order to descend, it is necessary to let out gas, which empties the envelope partially. To maintain the volume of the latter, it would be necessary therefore to carry a reserve supply of hydrogen to introduce into the envelope by means of a pump worked from the car. But when we consider that it would be requisite to carry this hydrogen compressed in very strong steel cylinders, we see, as a simple calculation conclusively testifies, that the weight of the necessary number of cylinders would be prohibitive. Consequently, the aeronaut is obliged to reject this method, which is perfect from the theoretical point of view, but impracticable in fact. He will rely, not upon a supplementary stock of hydrogen, but on air drawn from the surrounding atmosphere, to restore the original volume, and he will replace the hydrogen lost in the descent by an equal volume of air which he will introduce into the envelope by means of a pump.

At the same time, the danger that would be incurred by sending this air directly into the envelope of the balloon must not be overlooked. It would mingle with the remaining hydrogen, and produce a gas not only as inflammable as hydrogen, but an explosive element infinitely more dangerous. Here the ingenious artifice of the ballonnet comes into play.

Instead of making the interior of the balloon a single receptacle, constituting the whole interior, it is divided in two by a fabric partition liable to deformation (Fig. 6). This partition occupies the lower part of the balloon, and there forms a space called the *air-ballonnet*, communicating with the car below by a tube through which air can be pumped.

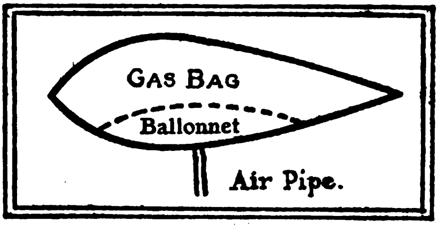


FIG. 6. The Air-ballonnet!

When the balloon, at the beginning of its ascent, is inflated fully with hydrogen, this fabric partition lies against the lower part of the envelope, exactly like a lining. As the balloon rises, the interior gas expands, because the outer air becomes less dense, and a portion of this gas escapes through automatic valves. The balloon therefore remains fully inflated so long as it rises. But when the descent begins, the gas, diminished by the quantity which has escaped during the ascent, no longer suffices to fill the envelope, which would then become flaccid, lose its original shape, and compromise the general equilibrium.

This is when the ballonnet comes into action. By means of a pump installed in the car, the aeronauts force air into the ballonnet, until the sum of the new volume it acquires and that of the remaining hydrogen gas reconstitute the total original volume of the aerostat. In this way the initial conditions of equilibrium are maintained always, in conformity with the calculations of the constructors.

The air-ballonnet, as will be seen, fulfils in aeronautics the same function as the "natatory gland" of fish, which enables these latter to maintain equilibrium in water under all conditions.

There is another way of ensuring this permanence of form so essential to the dirigible balloon. That is to make the balloon *rigid*. This last heroic solution has been adopted by

Count Zeppelin for his gigantic Zeppelin balloons, the largest of which attained 18,000 cubic metres.

To ensure this invariability of form, the balloon is furnished with an absolutely rigid metallic "carcase," made of aluminium tubes. This skeleton is divided into several compartments, and a very strong yet light fabric is stretched over the whole. This is the outer envelope, on which the resistance of the air is exercised during the flight of the airship. In addition, there is, in the interior of each compartment, a balloon of air-tight rubber fabric, which is inflated with hydrogen. Thus the airship contains a certain number of balloons, the sum of whose lifting power constitutes the total ascensional effort. The external form is invariable, owing to the material of the envelope and the framework on which it is stretched.

It may be seen at a glance what colossal difficulties such an arrangement presents; the difficulty of constructing a trellised cylinder 120 metres long and 11 metres wide, to say nothing of its expense; the labour in fixing the external envelope; and, finally, the complication of inflating the elementary balloons contained in each of the compartments. Successive catastrophes have shown the difficulty if not impossibility of managing such masses both at starting and landing. We shall discuss this question later on. But in any case it is difficult, and also very perilous, to give the body of an airship a rigid substructure.

Despite these difficulties, the indomitable perseverance of Count Zeppelin, the patriotism of his countrymen, who placed the requisite financial assistance at his disposal, the friendly support of the Emperor William, and the admirable German military aeronautical organisation, have enabled several of these vessels to be constructed, which, owing to the advantages arising from their large dimensions, have been able to accomplish some remarkable journeys, though six or seven came to an unfortunate end.

ALTITUDE STABILITY : ELEVATORS

This question of "stability" is of the utmost importance, therefore. It is the basis of aerial navigation.

Every one knows that the aerostat, whether dirigible or not, can rise or sink at will by the action of ballast or escape-valve. The skill of the aeronaut lies in economising the expenditure of these two essential elements; the ballonnet, under these conditions, ensures the permanence of the exterior form.

But this double action, expenditure of ballast and expenditure of gas, soon places the aerostat *hors de combat*. Therefore it is essential to preserve carefully a sufficient stock of ballast to guard against the always possible dangers of a difficult or unexpected landing; sufficient gas must be preserved also to enable a quantity thereof to escape at the last moment to descend sharply. Thus it has been found necessary to invent something else for dirigible aerostats destined to undertake long voyages, and this new appliance is the "elevator."

A dirigible balloon, indeed, requires motive power, which, through the intermediary of a propeller (generally a screw), provides the independent speed without which it is impossible to steer. But of this motive power, employed for horizontal propulsion, a small portion may be diverted which will serve for vertical propulsion; that is to say, in the particular case we are considering, it may be used to make the aerostat rise or sink slightly, without any expenditure either of gas or ballast.

The arrangement consists in providing the dirigible balloon with planes which can be inclined as desired, and are known as "elevators." These planes move about a horizontal axis, placed transversely to the axis of the balloon (Fig. 7), and may be disposed in the centre, or fore or aft of the apparatus. In our Figure, we have supposed that they are placed at the tail of the pisciform envelope. A glance at these two Figures will convince us of their controlling action; they raise or depress the "nose" of the balloon at will, just as the ordinary rudder turns it to the right or left. The same thing happens if they are placed in front. Generally speaking, it is difficult to attach them to the envelope itself, and thus they are placed on the car, as in the case of the *Clément-Bayard* (Fig. 24), where we see this rudder, in the form of three parallel planes, placed in front of the long car, immediately behind the screw propeller. This apparatus is also called the "stabilisator."

The elevators may be placed also towards the middle either of the envelope or of the car. In this case the action, by virtue of the resistance they offer to the air, no longer serves to raise or depress the stern or the bow, that is to say, to incline the balloon, but to lift or lower the whole body.

It has been proposed to obtain the same result by means of screws with vertical axes, which would, of course, revolve horizontally. Their action, in this case, would have the effect of raising or lowering the airship by exercising pressure thereon either from above or below, according to the direction in which they were rotated. A more rational proposition is to fit the propeller shaft with a universal joint, so that it could be inclined either upwards or downwards. But neither of these expedients is as simple or efficient as the elevator, which is now in general use.

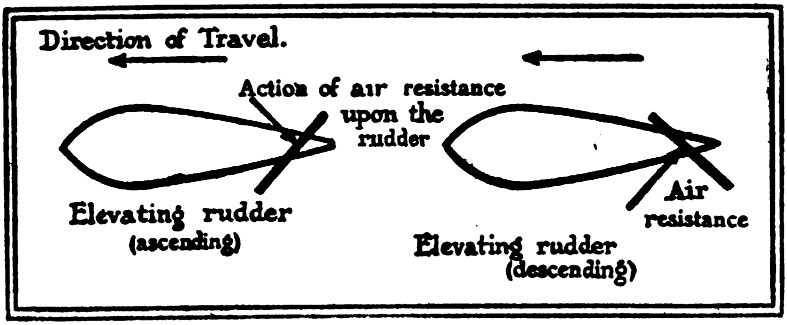

Direction of Travel.
Action of air resistance upon the rudder
Elevating rudder (ascending)
Air resistance
Elevating rudder (descending)

FIG. 7. Action of the elevator

The moving balloon is caused to ascend or descend by the action of the air upon the rudder, according to its inclination

STABILITY OF DIRECTION : LONGITUDINAL STABILITY

"Route Stability," or "Stability of Direction," consists of the following condition which the balloon ought to fulfil—its axis must always be turned in accordance with the direction of the course it is desired to follow (Fig. 8). This stability is a quality which is exercised in the horizontal plane; we must therefore suppose that in Fig. 8 the dirigible balloon is seen from above and is travelling parallel with the ground.

How is this stability to be ensured? In the following manner: as soon as the balloon shows a disposition to deviate from the direction it ought to follow, TT, a direction which is tangent to the course set down, it must be brought back by the resistance of the air itself. For this purpose, continuous use may be made of the "steering rudder," which, like the rudder of a boat, serves to direct the airship from right to left. But this method would be fatiguing to the helmsman, and not sufficiently efficient to prevent unforeseen divergences. Aeronauts, therefore, prefer to ensure stability of direction by the design of the balloon itself, and this is the chief reason for adopting the lines of the fish, with the larger end in front. Then the centre of gravity of the balloon is brought to the front, and the "leverage" of the stabilisating elements formed by the stern of the envelope is efficiently augmented.

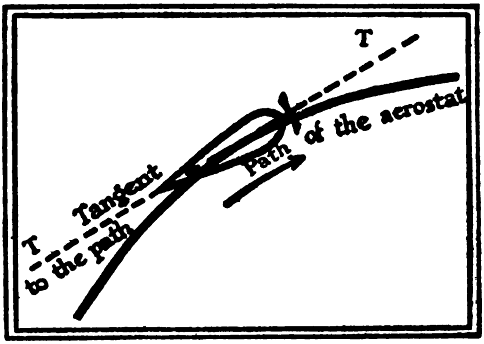


FIG. 8. Route stability

However, the envelope of the balloon itself would not suffice, so just astern of the latter "stabilisating surfaces" have been disposed, formed of vertical planes fixed to the envelope, forming, as it were, a keel for the dirigible analogous to the keel of a ship. By this means, stability of direction is obtained naturally, without having recourse to the ordinary rudder, which is used only for steering.

Still we have to consider "longitudinal stability." What is this third stability? It is the property of remaining always horizontal or nearly so, which the balloon ought to retain, through whatever evolutions its pilot may pass it. In other words, it is the property of not "pitching."

This longitudinal stability is much more important even than stability of direction. Should the latter be imperfect, the aeronaut corrects it readily by using his steering apparatus more frequently. But if longitudinal stability is defective, the balloon may incline in a dangerous manner, and here the necessity of an unvarying connection between the car and the envelope appears more important than ever.

If, in fact, the balloon and the car are united by unvarying attachments, the suspension being triangular when in a state of equilibrium, the thrust and the weight are in the extension of one another. If the balloon inclines, the car retaining its relative position, the weight is no longer in the prolongation of thrust; but then the two forces tend to "trim" the airship. If, on the contrary, the suspension is liable to displacement (Fig. 10), we see that if the dirigible be tilted for some reason, its equilibrium would not be restored by the action of the weight of its car and cargo.

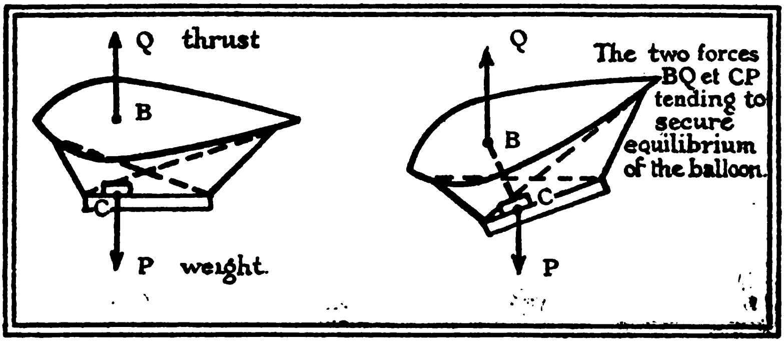

Q thrust
B
C
P weight.
Q
The two forces BQ et CP tending to secure equilibrium of the balloon.
B
C
P

Fig. 9. Longitudinal stability

The airship must maintain the position shown at left, and if, accidentally, it tilts as shown at right it must recover its horizontal position

Therefore, the suspension must be incapable of displacement, and for this reason the idea of making the balloon rigid, and of uniting it to its car by rigid attachments, has occurred often (*Zeppelin*, *Pax*, for instance). But absolute rigidity involves terrible drawbacks; all rigid balloons so far have finished up with accidents. Aeronauts in general have decided in favour of triangular suspension (Fig. 9); these are sufficiently unvarying, as long experience has shown.

One of the most serious causes of longitudinal instability is due to the gas which fills the balloon; its tendency is to augment any inclination produced accidentally. This gas, from its very nature, is compressible, and on the other hand, the envelope of supple material is essentially deformable. A transverse section of an inflated balloon would not therefore be a circle, but an ovoid figure (Fig. 11), the larger end of which would be uppermost. There are two reasons for this: in the first place, the traction of the suspensory ropes of the car compresses the envelope laterally from A to B and from A′ to B′, making it almost flat; in the second place, the interior gas, being lighter than air, tends to accumulate in the upper part, and this force acts obviously in the same manner as the former, deforming the transverse section of the balloon.

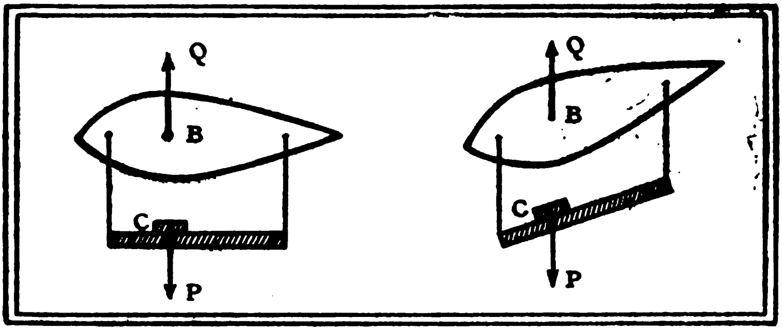


FIG. 10. Instability produced by parallel connections

The suspension being articulated, the centre of gravity always rests below the centre of thrust, B, even if the airship tilts: therefore it cannot recover itself

At a glance, this deformation would not appear to have any injurious influence on longitudinal stability; yet, the last cause we have put forward may be adverse to this stability. Let us suppose, for example, that the balloon tilts as in Fig. 12; the interior gas, which is lighter than air, immediately rushes to the upper part, leaving the lowered end insufficiently inflated. The centre of thrust B is displaced towards the right, and as the two forces which would tend to restore the equilibrium of the balloon, BP and CP, will be less and less distant from one another, this restoration will not take place. Such a contingency would be serious indeed if the balloon were imperfectly inflated, but with a full balloon, this accident is less to be dreaded. Thus the function of the ballonnet is doubly important, because it ensures permanent inflation, and consequently persistent stability, for the air of the ballonnet, imprisoned in its special envelope, cannot accumulate in the lowered part of the dirigible. Colonel Renard even subdivided the ballonnet into flexible compartments without any intercommunication in such a manner that the air contained therein could in no possible case accumulate by its own weight or inclination at either end thereof (Fig. 12 B).

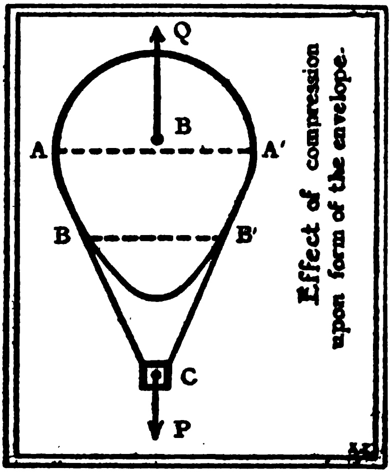


FIG. 11. Deformations of transverse section

The pressure of the suspension ropes flattens the "cheek" of the envelope, and gives it the shape of a pear on the transverse profile, instead of the original spherical form

Aeronauts have every reason to dread the inclination of airships, and to avoid them by every possible device. Resistance of the material, the suspension, &c., is calculated on the assumption that the airship will be horizontal, or very nearly so, in which case the strain is distributed equally throughout the suspension and on all the material. If, on the contrary, the airship should incline in an exaggerated and unforeseen fashion, there would be elements which carried no strain at all, while others would be overloaded; serious accidents have resulted from such a cause.

Accordingly the operation of filling the ballonnet is a most important operation in aeronautics. Many constructors now make it automatic in action. A pump is continually driving air into the ballonnet, while a valve in the latter opens as soon as the pressure of the air exceeds a given point; the superfluous air escapes into the atmosphere, and the pressure within resumes its normal value, ensuring the constant preservation of shape.

REALISATION OF DYNAMIC EQUILIBRIUM: CRITICAL SPEED: THE "EMPENNAGE"

It was in 1904 that Colonel Charles Renard first formulated the exact laws concerning the dynamic equilibrium of dirigible balloons, discovered the causes which render this equilibrium precarious, and at the same time indicated by what means it might be obtained completely. Let us now summarise briefly the results achieved by this distinguished officer.

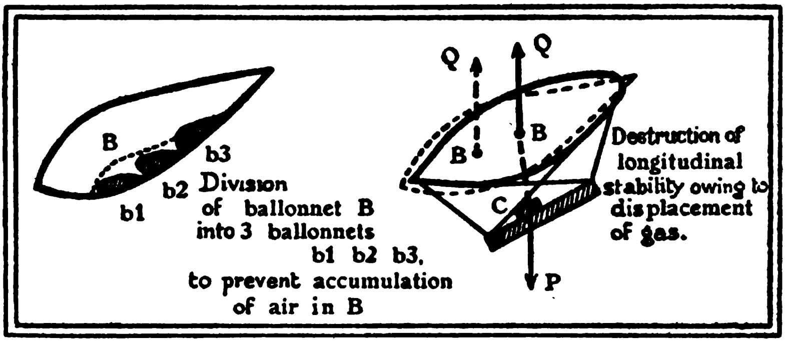

B
b3
b2
b1
Division of ballonnet B into 3 ballonnets b1 b2 b3, to prevent accumulation of air in B
Q
Q
B
B
C
P
Destruction of longitudinal stability owing to displacement of gas.

FIG. 12. Action of the ballonnet

We will commence by noting that if we took a symmetrical fusiform balloon, tapering equally at each end and suspended on a horizontal axis passing through its centre of gravity, this balloon would be in a state of "indifferent" longitudinal equilibrium (Fig. 13). If the axis of the balloon is horizontal, and if a horizontal current of air bears upon it, the balloon will be in equilibrium, but an equilibrium essentially "unstable," for it is proved, that so soon as the envelope thus suspended inclines ever so slightly, this inclination will increase until the axis of the balloon is perpendicular to the current of air; in other

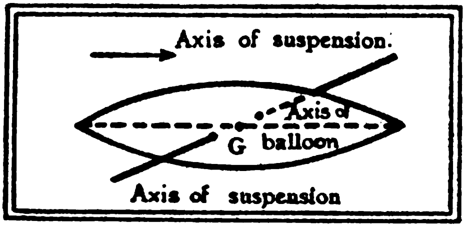


FIG. 13. Imperfect equilibrium

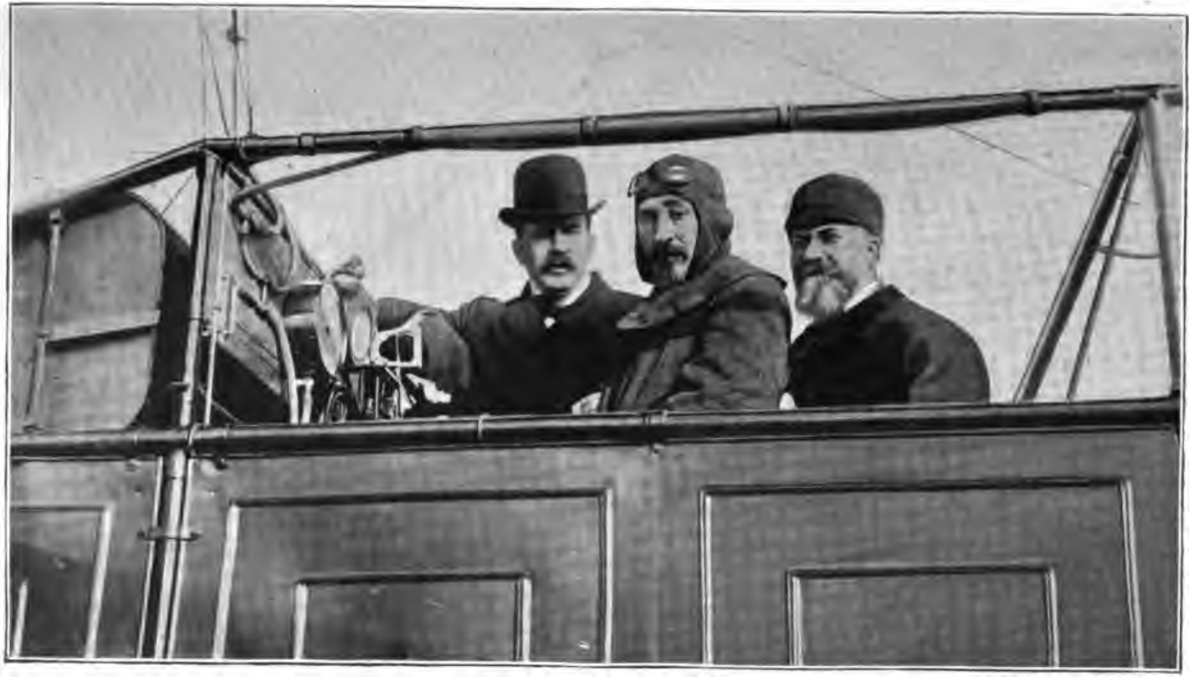
If the balloon assumed an inclined position the latter would increase steadily words, till it stands on end. This position is inadmissible, for it would show absolute instability.

If, instead of a symmetrical fusiform balloon, we take a pisciform balloon, with the larger end in front, the instability would still persist, though it would be diminished considerably. Here we are not in the domain of theory but of experience, for it was by dint of innumerable experiments, carried out with admirable method, that Colonel Renard obtained all the results we are now discussing. In the case of a pisciform balloon the disturbing effect is due, in unequal degrees, to the diameter of the balloon, its inclination and speed, whereas the stabilisating effect depends on the inclination and diameter of the balloon, but not upon the speed. The disturbing factor in the equilibrium is attributable solely therefore to speed, and develops very swiftly as the speed is increased.

It will be understood readily that there is a certain speed for which the two effects are equal, and beyond which the disturbing effect, depending on speed, will overpower the stabilisating effect. This velocity Colonel Renard called "critical speed." If this be exceeded, the equilibrium of the balloon becomes unstable. The most remarkable feature of Colonel Renard's brilliant labours in this field is, that they are not only the expression of scientific calculations, but, above all, of *experiments* conducted on highly skilled lines, experiments in which the gifted aeronaut submitted *keels* of various shapes and dimensions to the action of a current of air which he could modify at will.

The question arises naturally as to whether this "critical speed" is very high. As a matter of fact it is relatively slight, as the following figures will show. Let us take, for instance, a dirigible pisciform balloon of the type *La France*. Its critical speed is 10 metres a second, or 36 kilometres an hour, and a 24 horse-power motor suffices for this speed. Now the lightness of modern engines is such, that a balloon of this type could lift easily a motor of from 80 to 100 horse-power. With such a motor theoretically it might have a speed of 15 metres a second, or 55 kilometres per hour, but it could not accomplish this in practice; for, its critical speed being 36 kilometres, its equilibrium would become unstable if this

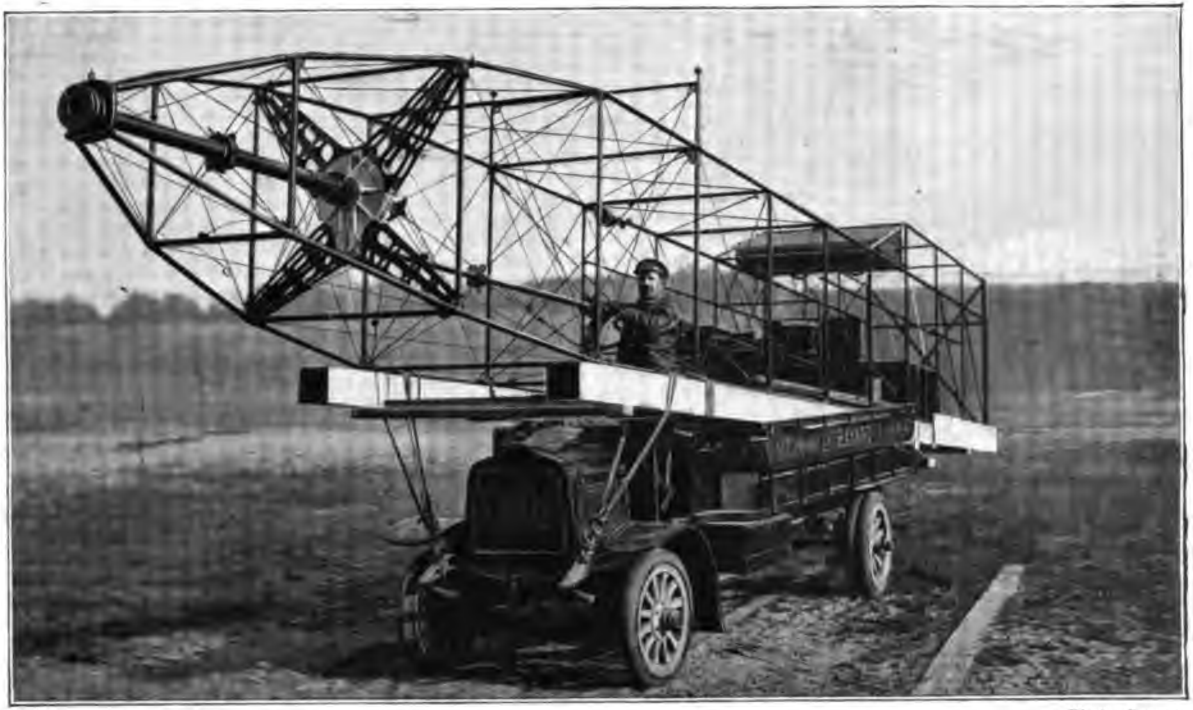
PLATE VII



Colonel Lowther M. Capazza M. Clément *Photo, Branger*

CAR OF THE "BAYARD-CLÉMENT NO. 1'

PLATE VIII



Photo, Branger

FORE PART OF THE CAR OF THE "BAYARD-CLÉMENT NO. 1"

Showing propellor shaft, reducing gear and motor transmission shaft below

were exceeded. In, fact long before this velocity was attained, the stability of the airship would become precarious and totally inadequate.

Therefore it would be useless to essay the lightening of the motor, that is to say to increase the speed of balloons, unless we had a means of ensuring its stability, for, as Colonel Renard wittily observed in the case we have quoted: "If the balloon were provided with a motor of 100 horse-power, the first 24 would drive it, and the other 76 would break our necks."

This means of stabilisation is the *empennage;* the systematic use of rigid planes, both vertical and horizontal, passing through the axis of the balloon, and placed well aft of the centre of gravity. The resemblance of a balloon thus fitted to a feathered arrow is obvious; hence the name of the apparatus.

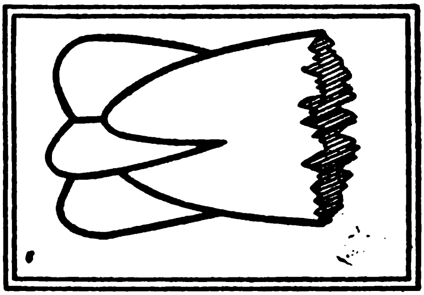


FIG. 14. Cruciform empennage of the *Patrie* and *République*

The empennage surfaces are rigid planes

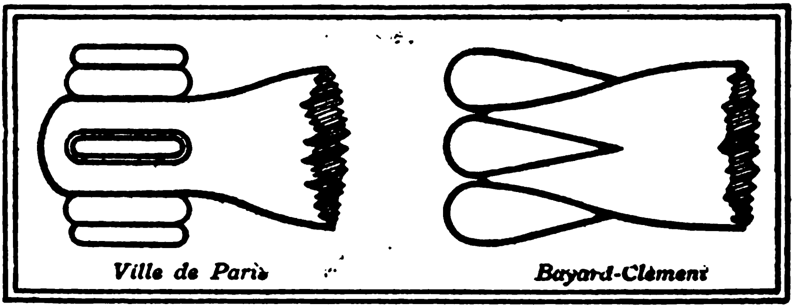


FIG. 15. Pneumatic empennages

The empennages are elongated ballonnets, the hydrogen with which they are inflated counteracting their weight

With a balloon of the size of *La France* (60 metres long and 10 metres in diameter), the surface necessary to achieve strict *empennation, i.e.,* to annul the disturbing effect, is 40 square metres, lying 25 metres behind the centre of gravity. By slightly augmenting the surface and the distance, a degree of security higher still is secured.

But how is this "empennation" to be carried out? In the *Lebaudy* balloon it was fulfilled by means of surfaces affixed to the framework between the balloon and the car; in *La Patrie*, a still better plan was adopted, for the feathered arrow was realised literally by fitting four surfaces in the form of a cross to the stern of the envelope, as shown in Fig. 14. Colonel Renard pointed out another method of obtaining the effect of the empennage without the use of rigid planes, difficult to fix to the envelope of the airship and tending to overload the prow. This was to affix to the stern of the envelope elongated ballonnets projecting from the body of the balloon. This method was adopted by M. Surcouf in two different forms: cylindrical ballonnets for M. Deutsch's *Ville de Paris* (Fig. 15), and conical ballonnets for M. Clément's *Bayard*. Being inflated with hydrogen, their weight is counteracted, and they no longer constitute a useless and unsymmetrical supplementary load to the airship.

There are other means by which such instability may be overcome; the use, for instance, of a very elongated car, which allows a considerable weight to be displaced from stem to stern. This method was adopted in the *Zeppelin;* but such an arrangement is difficult to work, and the empennage is at once simpler and very much safer.

POINT OF APPLICATION OF THE PROPELLING FORCE: "DEVIATION"

Where should the motive power which is to propel the dirigible balloon be applied? At what point of the complex system formed by the envelope, its rigging, &c., should the propulsive force act? We have to examine this question yet.

As the essential sustaining part of the airship is the envelope, it is this which offers the maximum resistance to the air. Theoretically, therefore, the propelling effort should be applied to the axis of the balloon itself, as many inventors have maintained. Several, indeed, have sought to put this theory into practice, notably the unfortunate Brazilian Severo d'Albuquerque with his balloon *Pax*, which ended in a catastrophe, and the constructor Rose, who produced a twin airship, the axis of the screw being between the two balloons which constituted his system.

This conception would be a perfectly just one if the car and the rigging offered no resistance to the air; but their resistance is far from negligible. The car has a transverse section of several square metres, and the sum of the surfaces, presented by the suspensory ropes is enormous. For instance suppose the latter to be steel cords of three strands, each of three threads, that is, nine threads to the cord; their diameter is about three millimetres; their length between the car and the balloon about ten metres. One of these ropes would therefore offer a resisting surface of about 300 square centimetres or three square decimetres; ten would represent a surface resistance of about one-third of a square metre, while sixty cords would equal two square metres. Add to this the sum of the sections of the knots, splices, pulleys, ropes used in the manœuvring of the vessel, transverse members, the pipe carrying the compressed air into the ballonnet by the aid of the special pump, the surfaces of the rigging, guide-ropes, &c., and finally the surfaces of the passengers, and a sum of resisting surfaces is soon obtained, beyond the sustaining envelope, and equal to a quarter, a third, and even more of a transverse section thereof. If, therefore, we represent the resistance offered by the envelope as BR (Fig. 16), and that offered by the car and its accessories as CR′, the motive-power AF must be applied at the point A, between B and C, and nearer to B than to C, to ensure the permanently horizontal position of the system under the combined action of motive and resistance efforts. But, on the other hand, it is difficult, at least in the present state of aeronautical construction, to attach the shaft of the screw to the envelope itself, without using rigid envelopes such as those of the *Zeppelin* or the *Pax*.

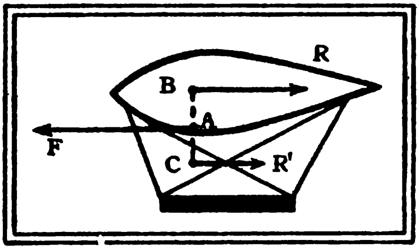


FIG. 16. Point for applying the propelling effort

The resistance of the air bears partly upon the envelope at the point, B, *and the car, together with its equipment, at* C. *Consequently the propelling effort should be applied at* A, *to overcome the resultant of the two resistances*

Perforce, therefore, the aeronaut has to be content to apply the propelling power to the car. Hence a tendency in the dirigible balloon to tip up at the nose, because the force F is not exercised directly at the point of application A, the resultant of the two forces R and R′. The constant use of the elevating rudder becomes necessary, and we find that this tilting is the more pronounced the farther the car is from the envelope. The term "deviation" is used to describe this tilting effect produced by the action of the propeller.

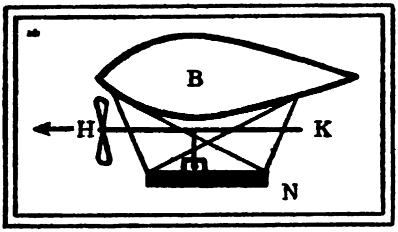


FIG. 17. Rational disposition of the screw

It will be understood that this "deviation" will be modified in proportion as the car is brought closer to the balloon; but such is limited by the danger of installing an explosion motor too closely to an envelope containing an inflammable gas. The golden mean must be observed. If the car were too far from the balloon, the tilting effect would be very great, and the balloon would incline without advancing.

Comte de la Vaulx found a very ingenious solution of this difficulty. He fixed the screw H (Fig. 17) to a shaft HK at a point between the envelope and the car. The latter contains the motor which works the shaft HK through a transmission system. This is a very rational solution, and it is possible that it may be followed widely in airship construction.

As to the position of the propeller, this may vary considerably. Colonel Renard and M. Surcouf, the constructor of the dirigibles *Bayard-Clément* and *Ville de Paris*, place it at the prow of the car; under these conditions it *draws* the balloon. Other constructors place it at the stern. This was the plan adopted by Giffard, Dupuy de Lôme, and the brothers Tissandier. M. Julliot, the engineer, to whom we owe the *Lebaudy* and the *Patrie*, introduced two screws, which he fixed outside the car, on either side and almost in the centre. We see then that various arrangements are in use. But on the whole there seems to be a preference to place the propeller at the prow of the car.

CHAPTER III

THE WIND AND DIRIGIBLE BALLOONS

THE AERONAUT'S WORST ENEMY : HOW WIND INTERVENES IN THE PROBLEM OF AERIAL NAVIGATION : RELATION BETWEEN WIND AND AIRSHIP SPEED : THE "APPROACHABLE ANGLE" : ACCESSIBLE AND INACCESSIBLE REGIONS

WHAT IS WIND?

WIND is simple to define: it is the movement of atmospheric masses in a horizontal direction; the displacement of air parallel to the surface of the earth. Its study is one of the principal objects of that branch of physics called meteorology.

Meteorology, or rather the study of atmospheric phenomena over continents, otherwise called "Continental meteorology," is relatively backward, as compared with nautical meteorology. The reason is that the immense and uniform surface of the ocean allows molecules of air to obey the laws of equilibrium and the movement of fluids freely, whereas the surface of the land, bristling with an infinite variety of obstacles, offers much greater difficulty to the establishment of clearly defined laws. Moreover, the waters of the sea cover nearly three-quarters of the surface of the terrestrial globe; it is above them, therefore, that the great laws of atmospheric movements are demonstrated. Finally, all sailors are meteorologists, whereas on land keen observers are rare. This fact has given rise to the sarcastic definition of meteorology as a science which consists in knowing what kind of weather it was yesterday.

Yet it is with winds blowing over land that aeronauts will have to reckon, at least, in their early days. The moment has not yet come (though, indeed, it may not be far distant) when, launching themselves boldly over the sea, they will have to struggle with oceanic winds, and consequently to experience personally the laws of nautical meteorology.

The wind is differentiated by its *direction* and its *velocity*, or its *force*. Its *direction* is indicated from the point of the horizon whence it blows; a north-east wind is a wind which blows from the north-east, and so forth; the so-called "compass-card" of the mariner gives all wind directions by initials (Fig. 18).

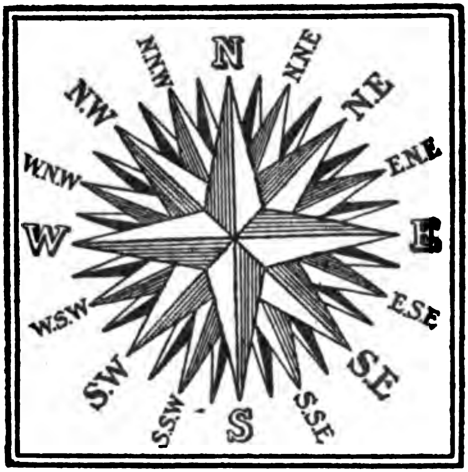


FIG. 18. Compass-card

The velocity of the wind is reckoned in metres per second; we should say, for instance, a wind of 7·50 m. per second. By multiplying the speed in metres per second by the factor of 3600, the number of seconds in an hour, we get the speed for the wind in kilometres per hour. A wind of 10 metres a second is, therefore, 36 kilometres an hour; the wind of 7·50 m. corresponds to 26 kilometres an hour.

The force of the wind may be measured by the pressure it exercises upon a stationary object opposed perpendicularly thereto. Sailors have deduced from centuries of navigation in sailing-vessels that the pressure of a wind making a metre per second upon a surface of one square metre perpendicular to its direction is 0·125 m., or, in plain words, 125 grammes per square metre. This pressure increases in proportion to the surface of resistance, and in proportion to the *square* of the wind's speed. With a wind blowing 2 metres per second, it would amount therefore to 4 × 0·125 kg., or 500 grammes per square metre; for a wind travelling at a speed of 4 metres, it would be 16 × 0·125, or 2 kilogrammes per square metre, and so on.

When the velocity of the wind becomes considerable, the pressure it exercises upon fixed obstacles becomes enormous; a wind of 25 metres per second, or 90 kilometres an hour, would exercise a pressure of 25 × 25 × 0·125, or nearly 80 kilogrammes per square metre. The accident which resulted in the loss of the dirigible balloon *La Patrie* was due to this tremendous force.

WIND AND THE AERONAUT

Let us now define this idea of the wind rather more precisely, for, in the special case we are studying, an inaccurate idea thereof is formed often, and it must not be forgotten that it is in the very bosom of the atmosphere that we encounter it with our dirigible balloons. Let us therefore study the wind, not in its relation to the ground, but in its relation to the airship.

If we were in a spherical balloon, it would be susceptible to this pressure so long as, in process of inflation, it was held to the ground by mooring ropes; the "force of the wind" would tend to beat it down upon the ground or to tear it from the hands of those who were holding and keeping it stationary. But so soon as its moorings are cast off, so soon as the balloon rises into the air without any propelling mechanism, the aeronaut is only conscious of absolute calm: the wind, in fact, is imperceptible to him, because the *wind* is a *relative* movement of the molecules of air in respect of an observer stationed upon the ground. Once in the air, a spherical balloon forms part of the atmosphere. It is carried along by the wind itself, and moves *with it;* it is not displaced *in relation to it.* So long as the balloon neither rises nor sinks, a little banderole fastened to the rigging hangs vertically, without fluttering in the wind as it would were the balloon held to the ground.

Consequently so far as concerns the aeronaut who belongs, not to the earth, but to the atmosphere, wind is non-existent; these were the words enunciated by Colonel Renard the first time he described in public his experiments in connection with the steering of balloons. If then we were to take an airship, dirigible or otherwise, everything in connection therewith would happen as if the air were still. If the balloon is dirigible, that is to say, if it is furnished with a motor and a propeller, and if these forms have been logically designed, the aeronaut could move in this atmosphere in any direction, as if the wind did not exist; as his balloon advanced, he would have the same sensation as if he were passing through an absolutely calm atmosphere. He would have an impression of *wind*, but this wind would have nothing in common with that which blows over the surface of the earth; it would be a current of air from the stem to the stern of the balloon, *created by the aeronaut himself by his advance;* it would be the result of the displacement of the balloon by its propeller. Stop the latter, and calm would be restored at once; the aerial navigator would feel no longer the slightest current of air.

To sum up, then, we may say with Colonel Renard that "the balloon belongs to, and has nothing to fear from, the air. If it is furnished with a propeller and a motor, in a word, if it is dirigible, the wind changes nothing, neither in the nature of the efforts it has to undergo during the voyage nor in the speed of its displacement in relation to the aerial ocean in which it floats. Everything is just as if, the air being perfectly still, the earth were flying along beneath with a speed equal and contrary to that of the wind." *

In the case of the aerostat, as of the airship, the wind therefore signifies, from the final result point of view, *a relative displacement of the ground,* exactly as if the aerial swimmer being stationary, the earth were carried along by the current of air. From this we shall note interesting results, which will show us the limitations of the efficient action of dirigible balloons.

INDEPENDENT SPEED AND WIND VELOCITY : THE APPROACHABLE ANGLE

Let us imagine (Fig. 19) hovering over Paris, an "aerial fleet," † comprising a central balloon, playing the part of a flagship, occupying the centre of a circle formed by six aerial cruisers. All the engines have been stopped, and the flotilla is for the moment motionless in relation to the air. The wind is blowing from the west at a speed of 8 metres per second, that is say, 29 kilometres an hour.

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* Colonel Ch. Renard: *La Navigation aérienne*, a lecture delivered at a meeting of the Société des Amis de la Science, April 8, 1886.

† *Ibid.*

The admiral's balloon issues a command: the six cruisers are to effect a reconnaissance, each going off in a different direction, while the balloon in command will remain stationary to await their return. Let us imagine all these cruisers travelling at the same speed, 6·50 metres a second, for instance, or 22 kilometres an hour: this is the independent speed of each in calm air. At the end of an hour they would all be 22 kilometres from the admiral's balloon; in other words, they would be distributed on the circumference of a circle having a radius of 22 kilometres, the geometrical centre of which would be occupied by the "flagship." This is what would be happening *in the air*. Now let us see how our seven balloons have been disposed *above the ground*, taking into account the wind, which is blowing at the rate of 8 metres a second, or 29 kilometres an hour.

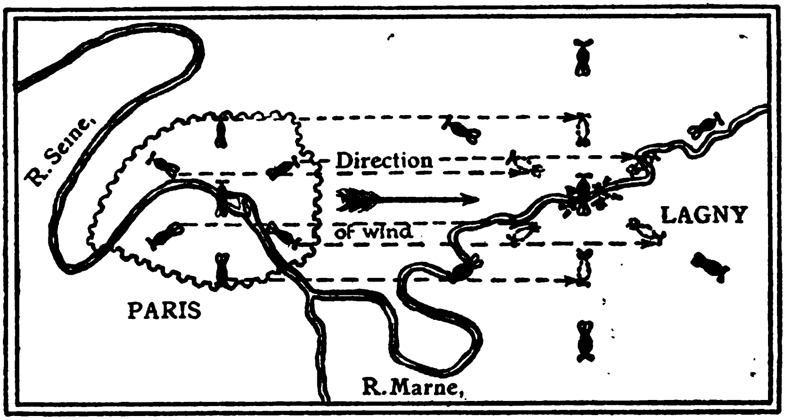


FIG. 19. Example of relative wind

The earth will appear to have fled towards the west precisely at the speed of the wind, that is, 29 kilometres an hour. Thus Paris, which just now was immediately under the admiral's balloon, will be removed 29 kilometres west of the "flagship," which, having stopped its engine, has remained motionless in the air. Below this balloon will stretch a new region, that of the Marne, and Lagny is now the centre of the circle with a radius of 22 kilometres, on the circumference of which the six aerial cruisers are distributed symmetrically.

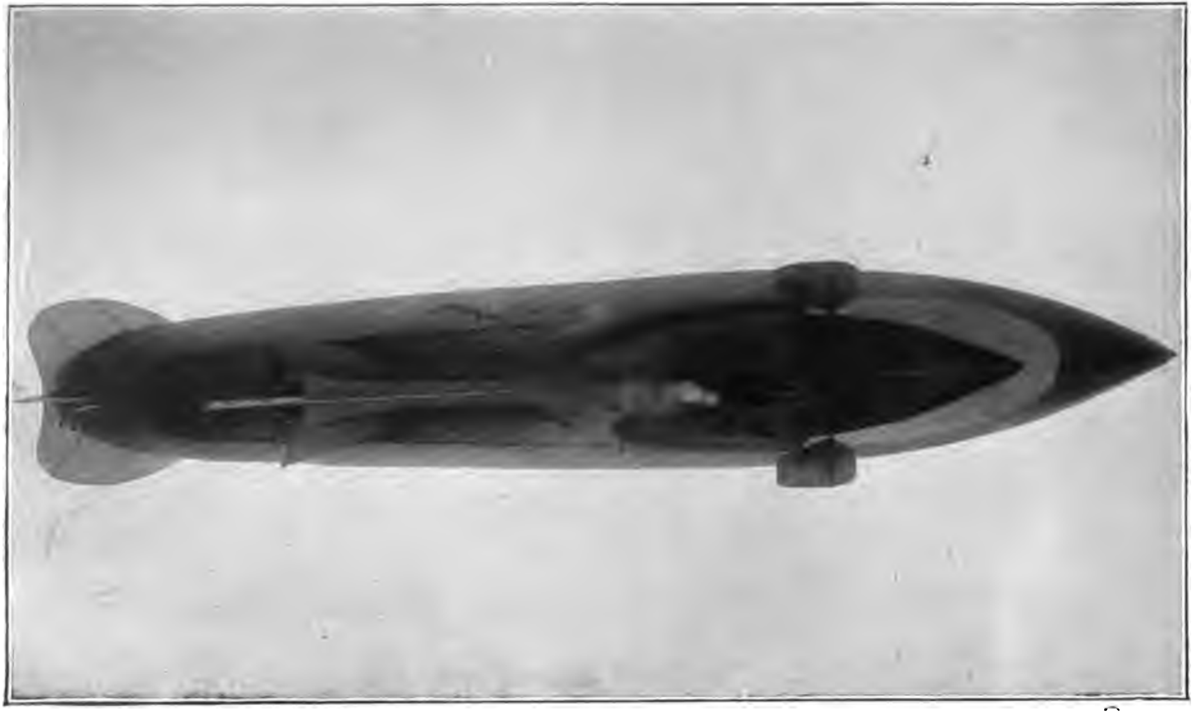
Consequently the west wind has had no effect really but that of displacing the whole aerial fleet *en bloc* towards the east by a distance of 29 kilometres under the wind. Therefore it has made no change in the relative positions of the airships.

Equipped with this result, we may determine now the points which the dirigible balloon could attempt to reach, taking into account its independent speed and the velocity of the wind.

Let us imagine our balloon, with its motor and propeller, having an independent speed of 6·50 metres per second; this, as we have already explained, amounts to saying that in absolutely calm air it would travel 22 kilometres an hour. Let us suppose that this independent speed differs from that of the wind, which we will take to be 8 metres a second (29 kilometres an hour). The balloon sets out from the point P (Fig. 20), in the direction PA, at an independent speed represented by the length, PB: this would mean that, if there were no wind, at the end of an hour it would have arrived at B. But the wind is blowing in the direction PS with a velocity represented by PV. The balloon, therefore, will travel along the route indicated in length and in direction by the diagonal PR of the parallelogram PBVR, and at the end of an hour, under the combined action of its independent speed BP and that of the wind, PV, it will have arrived at the point R, having throughout preserved the direction represented by the silhouettes (1) and (2). Consequently should the velocity of the wind be greater than that of the airship, and should it be directly opposed to the latter, there would be regions in the atmosphere inaccessible to the airship, which could deviate only by the aid of its motor from the direction of the wind, as is shown in Fig. 20. Now we will look more closely into this question. But a little careful attention on the part of the reader is necessary, for it must be pointed out that the whole secret of diriginlity in the air is explained in the following paragraphs. Three varying conditions might prevail:

1. *The independent speed of the balloon is less than that of the wind.* (Fig. 21.) Let P be the starting-point of the balloon, and let us take the line PA to represent its independent speed.

PLATE IX

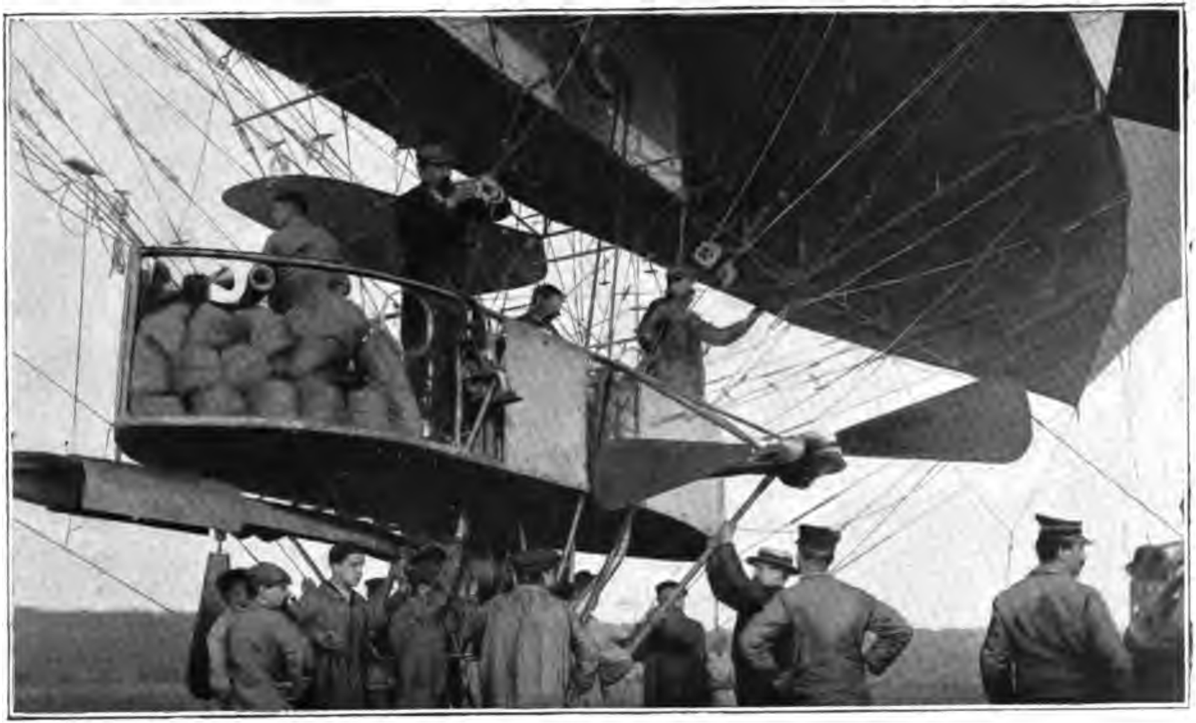


Photo, *Raffaële*

THE DIRIGIBLE "PATRIE" FROM BELOW

Showing the horizontal stabilisating empennage, and the elevator at the front

PLATE X



THE CAR OF THE "RÉPUBLIQUE"
Showing bags of sand in the car

Photo, Branger

This means that if the air were calm, at the end of an hour the airship would find itself somewhere on the circumference of the circle C, the centre of which is P, and the radius of which corresponds to the speed PA. But the wind is blowing with a speed V, greater than *v*: accordingly, the whole circle, C, at the end of an hour is transported to C′, and the balloon will be somewhere on this new circle C′, which is, from this very fact, the circle of points approachable in the space of an hour, the distance, PP′, being equal to the velocity of the wind. *Therefore the only points of the space which the balloon can reach will be those comprised within the angle formed by the tangents leading from the point* P *to the circle* C′, *i.e.*, comprised in the region which is shaded in the figure. All the remaining space would be inaccessible to the balloon. Consequently the *accessible angle* will be greater, the less the difference between the velocity of the wind and the independent speed of the balloon. The space would be *nil* if the speed of the balloon itself were *nil;* this is the case with free balloons, which can only move along the line PP′.

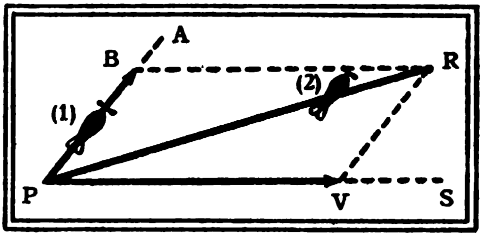


FIG. 20. Combined effects of wind and independent speed

The airship sets out in the direction, P, A; *but the wind blows,* P, S, *consequently the airship makes diagonal path,* P, R

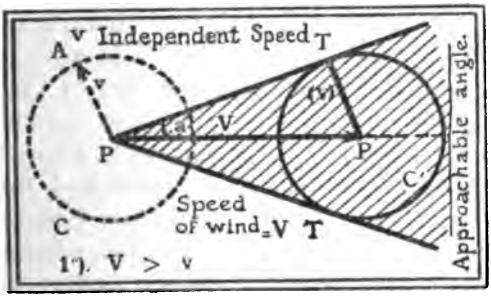


FIG. 21. Instance where the independent speed is less than wind velocity

The balloon can manœuvre only in the atmospheric space indicated by the shading

2. *The independent speed of the balloon is equal to the wind velocity* (Fig. 22).—The balloon is at the point P, its independent speed is PA, which is equal to the velocity of the wind.

If there were no wind, the balloon at the end of an hour would be somewhere on the circumference of the circle C; but the wind is blowing with the speed PP′, exactly equal to that of the airship itself; the circle C is therefore transported to C′ and at the end of an hour the balloon is on the circumference of C′. The shaded angle in Fig. 21, which has become more and more obtuse as the values of the two speeds approximated, becomes equal to two right angles, and the accessible region comprises the entire half of the space; is to the right of the tangent from the point P to the circle C′.

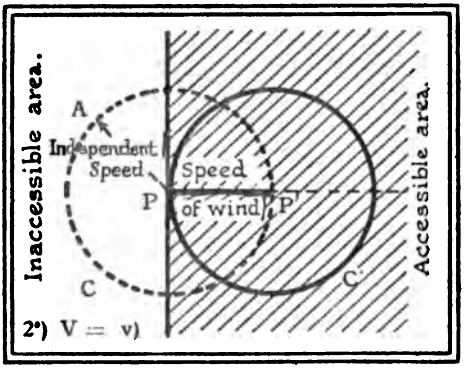


Fig. 22. Case where independent speed equals wind velocity

The airship is able to move in the whole half of the shaded area to the right of its starting-point

3. *The independent speed of the balloon is greater than the velocity of the wind* (Fig. 23).—In this case there is no special angle to define the accessible regions; the whole space is available to the airship, even in the direction contrary to that of the wind, and if the balloon goes dead against the current of air, it will advance *in respect to the ground* with a speed equal to the difference between its independent speed and the velocity of the wind: *therefore all space is accessible to a dirigible balloon whose independent speed is greater than the wind velocity.* The latter is the essential and sufficient condition governing perfect dirigibility.

PRESENT CONDITIONS OF DIRIGIBILITY IN RELATION TO THE WIND

We know now under what conditions an aeronaut can hope to reach any given point. Are these conditions compatible with the average state of the atmosphere; in other words, with the average wind velocities prevailing in our part of the world? Here we must rely on observation alone for a satisfactory answer.

Our official meteorologists are silent on this point as on many others in their treatises; so it has been requisite for our aeronauts to make the experiments necessary to obtain the results which are indispensable to them. Such experiments have been carried out for many years at the Chalais-Meudon military establishment. These very interesting results are summarised in the Table on p. 44. The first column gives the velocity of the wind in metres per second; the second, the corresponding velocity in kilometres per hour; the third, the possibilities of encountering a wind of the velocity denoted in fractions of a thousand. Thus, for instance, if we take a wind of 5 metres a second, or 18 kilometres an hour, the possibility of having a lighter wind will be 323 thousandths; in other words, there will be 323 chances to 1000 that the wind will be blowing at a velocity less than 18 kilometres an hour. The fourth column shows the number of days per year when, on an average, a wind of less velocity than those indicated in the first two columns will be prevailing. The final figures are those which will throw most light on the present conditions of dirigibility for the aeronaut.

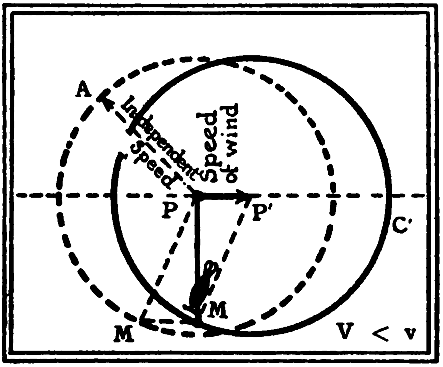


FIG. 23. The airship's independent speed is greater than the wind velocity, so that it can go anywhere

It must be pointed out that these results apply *to the vicinity of Paris*, where the observations on which they are based were effected.

The importance of these results is at once apparent, especially if we translate the average chances of the wind into "numbers of days per year," as I have done here.

Thus, let us take the speed of 10 metres a second, or 36 kilometres an hour. According to the following Table, there are

258 days in the year when the speed of the wind in the neighbourhood of Paris is, generally speaking, less than 36 kilometres an hour. Therefore a dirigible balloon having an independent speed of 10 metres per second could drive against the wind, on an average, 258 days out of 365; if the balloon has a minimum independent speed of 12·50 metres per second, that is to say 45 kilometres an hour (which is the speed of the *Bayard-Clément*, the *République* and the *Ville de Paris*), we see that it would be dirigible, on an average, for 297 days out of 365, that is to say, about ten months out of the twelve. Now, as I have stated already, this speed is attained by all the latest airships.

Velocity of the wind in metres per second	Velocity of the wind in kilometres per hour	Possibilities (in parts of a thousand) that the wind velocity will be less than that shown in first two columns	Number of days in the year when there would be a possibility of wind velocity being less than that in the first two columns
Metres	Kilometres	Thousandths	Days
2·50	9	109	39
5·00	18	323	117
7·50	27	543	197
10·00	36	708	258
12·50	45	815	297
15·00	54	888	323
17·50	63	937	342
20·00	72	963	350
22·50	81	978	354
25·00	90	986	358
27·50	99	991	361
30·00	108	995	363
32·50	117	996	364
35·00	126	998	364
37·50	135	999	364
40·00	144	1000	365
42·50	153	1000	365
45·00	162	1000	365

As a result we may affirm, figures in hand, *that the problem of aerial navigation by dirigible balloon is solved completely.*

Of course there are exceptional cases: thus, the probability of winds travelling faster than 35 metres a second, that is to say hurricanes blowing at a rate of 125 kilometres an hour and even more, is *nil*, or almost so; in other words, 999 times out of a thousand the chances would be in favour of a less violent wind. Occasionally such winds do occur but they are accidents; they devastate gardens, and damage buildings, yet are exceptional eventualities.

There is nevertheless, one important point in regard to the velocity of the wind—the speed of atmospheric currents increases very rapidly as we rise into the air. In Paris, owing to the Eiffel Tower facilitating the observation of such phenomena, it has been ascertained that whereas the *average* velocity of the wind in the course of the year is about 2 metres per second (7·200 km. per hour), on a level with the housetops, the average rises to more than 8 metres per second (about 29 kilometres an hour) at the top of the tower. Therefore aeronauts must take this circumstance very carefully into account, if they wish to form an accurate idea of the power of the wind against which their balloons will have to struggle when a voyage is to take place, not just above the ground, but at a certain altitude in the atmosphere.

We see, too, that if constructors accomplish the short stride representing the next advance in aeronautics, and attain a speed of 20 metres per second or 72 kilometres an hour as the "independent" speed of airships, such will be able to 350 travel ~~360~~ days a year in our latitude; this would be absolute solution, for the days when the wind velocity is higher than 20 metres a second are days of clearly defined bad weather, and are not very frequent fortunately.

Therefore immediate progress will tend towards augmenting the power and the output of the motor, together with improvements in the quality of the envelopes. The latter will have to be made capable of resisting the increased pressures of the air arising from greater speed in the flight of the future.

CHAPTER IV

CONSTRUCTION AND MANAGEMENT OF A DIRIGIBLE BALLOON

APPLICATION OF THE PRECEDING PRINCIPLES : HOW TO CONSTRUCT AN AIRSHIP : HOW TO DISPOSE THE MOTOR AND PROPELLER : ELEVATOR AND RUDDER : WHAT ARE THE TRAVELLING SENSATIONS IN A DIRIGIBLE ?

THE ENVELOPE AND ITS OUTLINE

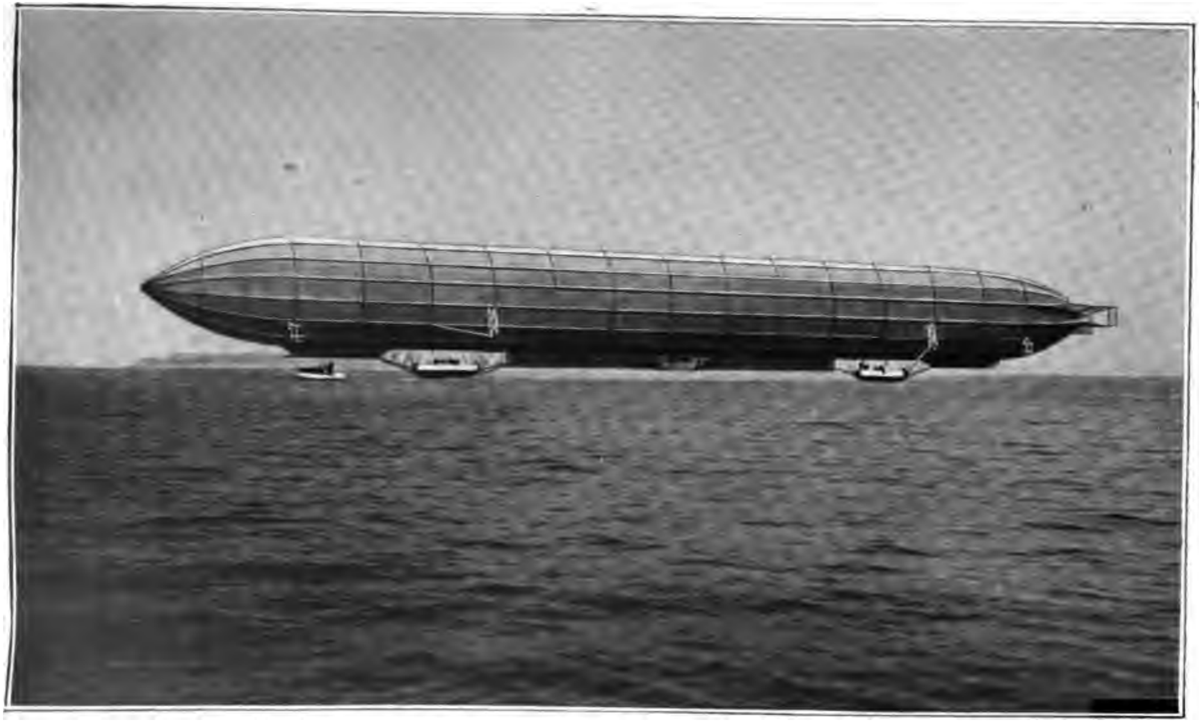
WE have shown what are the fundamental principles governing aerial navigation by dirigible balloons. We must see now how these principles are to be applied in the construction of those airships from which practical results may be expected.

The construction of the envelope is the first thing to be done. We have said that it must be light, strong, and impervious to hydrogen. All, or practically all, modern dirigible balloons have envelopes of rubbered material consisting of two layers of fabric with a layer of rubber between them. This material, the use of which occurred first to the engineer Farcot, weighs 300 grammes per square metre, and will withstand a strain of 1800 grammes per metre. Very often, after the envelope is completed, it is coated with a layer of chromate of lead, to absorb those solar rays which, by their actinic action, might affect the rubber; it was the colour of this medium which suggested the nickname for M. Lebaudy's balloon.

The *outline* of the envelope is important, for the exterior form of the airship ought to correspond to the minimum of effort required for propulsion through the air, while ensuring longitudinal stability. Thus the curved outlines of modern airships have been studied with the utmost mathematical precision.

The modern balloon, according to Renard, should be *pisci-*

PLATE XI

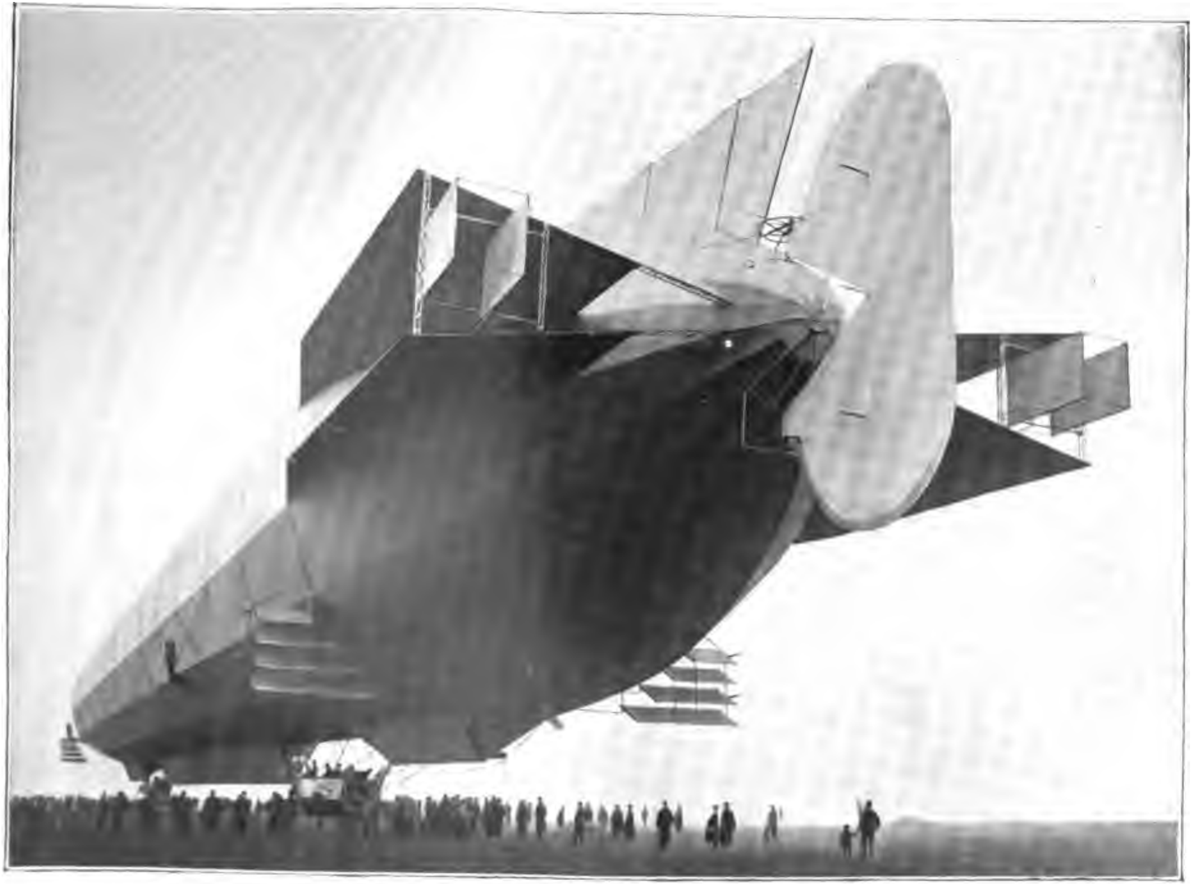


Photo, Rol

THE FIRST GERMAN DIRIGIBLE "ZEPPELIN" MANŒUVRING ABOVE LAKE CONSTANCE

The prototype of the rigid airship in which an inner skeleton secures indeformability of the envelope

PLATE XII



THE STERN OF THE "ZEPPELIN" *Photo, Branger*

either side. Two propellers at left and a blade of one on right can be seen *form*, with the larger end forward, after the manner of fishes and birds, otherwise there will be a risk of low efficiency (examples of which are given in the following chapter). But the profile and the elongation still have to be considered.

The envelopes constitute what is known in geometry as "surfaces of revolution," in the sense that they may be considered as evolving by the rotation round their longitudinal axes, the curve which defines their profile. The constructor commences by fixing the length of the balloon, its maximum diameter, and the position of the latter in the length of the envelope. After this he calculates the profile, generally formed since Renard's time, of two parabolas united; these parabolas are either simple or of the superior degree; but these are mathematical details which I need indicate only. When the envelope is calculated, it is drawn, and the templates necessary for cutting out the pieces of material are made; the latter, sewn together, constitute the body of the balloon.

We will take the *Clément Bayard* as our type of dirigible balloon. This vessel is familiar to me since I have made several ascents and voyages therein, while the perfection of its construction and manœuvring qualities entitle it to be cited as a typical example of French aeronautics.

CONSTRUCTION OF THE ENVELOPE: THE GAS

The profile of the envelope (Fig. 24) is formed by two parabolas of the third degree. The envelope is made of panels sewn together; its total volume is 3500 cubic metres.

Its surface is 2250 square metres. It is 56·25 metres in length and the maximum diameter is 10·58 metres. This envelope is inflated with pure hydrogen gas; in spite of the high price of this gas, which costs 1 franc and sometimes more per cubic metre, it is preferable to coal gas, on account of its great lifting power, no matter how cheap the latter may be. Moreover, balloon fabric is now so perfect that it reduces the loss of gas by exudation to an insignificant degree.

In the middle of the envelope is a *ripping valve*. This is an aperture in the upper part of the envelope covered by a band of fabric which can be torn off in an instant by the pull of a cord, should a rapid descent become necessary. This action is effected from the car. At the stern is the pneumatic *empennage*, consisting of four spherico-conical ballonnets, tangent to the back part of the envelope, and communicating therewith through holes. The air-ballonnet proper, divided into two parts, is 23 metres long, and has a volume of 1100 cubic metres.

The balloon is furnished with four automatic valves; two for the hydrogen gas, which open automatically as soon as the internal pressure equals 40 millimetres of water, and two for the air, opening when the pressure equals 30 millimetres. These two pressures are indicated by two gauges placed on the front of the bridge under the eyes of the pilot. If a valve were not working automatically, he would be warned therefore, and could work it manually by pulling a cord. The air is forced continually into the ballonnet by a fan pumping 1800 litres per minute, and driven through transmission from the motor. When this breaks down, the fan can be worked by hand.

The suspensions are thin steel cables of three strands, each of three threads. Some of them are 3, others 4 millimetres, in diameter, and they can withstand strains of 400 and 600 kilogrammes respectively. They terminate in "goose's-feet" of hemp fastened to boxwood stakes, and the latter are encased in a "girth" sewn into the fabric, which forms the envelope of the balloon. The net is thus rendered unnecessary, and this facilitates the passage of the molecules of air along the envelope, owing to the resistance offered by the obstruction from loops and knots being eliminated.

Beneath the "suspension girth" is placed the lifting girth, also sewn to the fabric. The "lifts" are steel ropes, which are oblique in relation to the length of the balloon, and secure that indispensable triangular suspension that assures the solidity of the car and the envelope, both in longitudinal and lateral directions. These lifts connect together by four "knots," which also constitute the fixed points of the suspension. These knots may be seen distinctly in the diagram.

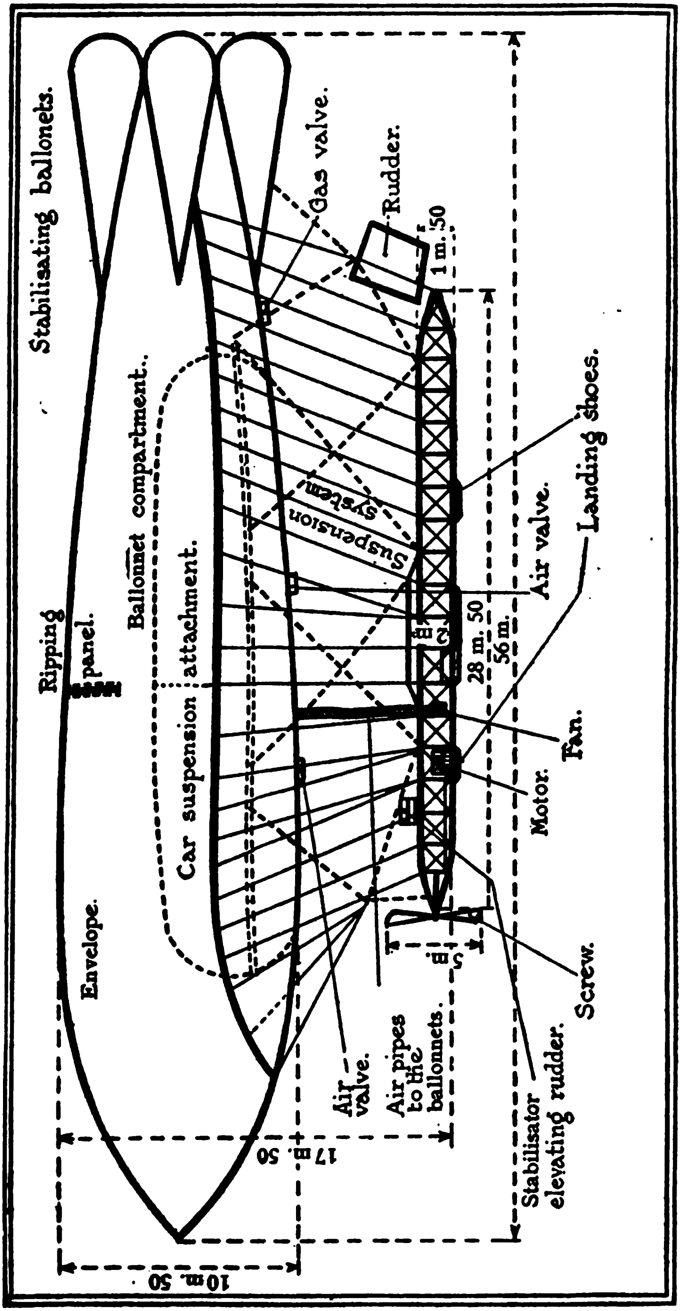


FIG. 24. The dirigible balloon "Bayard-Clément"

THE CAR, RUDDER, ELEVATOR, AND MOTOR

The car is built up of a series of cubes of steel tubes of 30 and 40 millimetres diameter. The sides of the cubes measure 1·50 metres, and their contiguity forms the car. The sides of these cubes are made rigid by steel wire diagonals fitted with stretchers. The central part of the car has a height of 2 metres; its total length is 28 metres.

The steering rudder is carried at the stern; it is double, and its surface is about 15 square metres. It is composed of rubber fabric stretched upon a steel tube framework having its axis connected to the car by means of a cardan joint. The fourth knot of the lifting rope (that of the stern) and two stretchers serve to hold it.

The "stabilisator," or elevator, fitted to the front of the car, is in reality a "triplane" turning about a horizontal axis, and able to be inclined from 16 to 17 degrees above or below the horizontal. Its efficiency is considerable, inasmuch as in accordance with specific calculations, when the machine is at full speed, the effect of the stabilisator is more or less equivalent to 100 kilogrammes of ballast, according to the degree of upward or downward longitudinal inclination. The elevator and the rudder are controlled through steel cables and chains, by two wheels placed upon the bridge on the right and left respectively; these wheels, like those of motor-cars, are "irreversible."

In the centre of the car is the passengers' accommodation as well as the pilot's position. The latter, by raising the floor of the car, is elevated about 50 centimetres. The pilot, standing on the left, has the steering wheel under his hand; on his right is his assistant holding the wheel of the elevator. Forward is the motor room, and the pilot can communicate directly with the engineer. A vertical panel on the front of the bridge carries the whole of the controlling instruments. These are the balloon and air-ballonnet gauges; the barometer to indicate continuously the altitude; a barograph; the dynamometer which permanently records the tractive effort of the propeller; and lastly, the speedometer registering the number of revolutions per minute made by the motor. In addition to this is a shelf carrying the chart and a compass, to indicate the course to be followed, the latter being well compensated owing to the masses of iron and steel in the balloon. Through the passengers' space extends a large suspended table carrying the road maps, indispensable to the voyage and for guidance by comparison with the country spread immediately below. Lastly under the car are the "skates" which enable the airship to alight without the car being injured by contact with the ground.

The engine is an explosion motor, such as are used in automobiles. It is multicylindrical, works with a mixture of air and petrol gas, and is of 105 horse-power. The special materials of which it is constructed ensures, at one and the same time, great solidity and a remarkable regularity in running, without forfeiting that lightness indispensable to an aeronautical motor. It weighs 352 kilogrammes all told. The weight of the petrol tanks is 64 kilogrammes, that of the oil reservoirs 10 kilogrammes. The motor is water-cooled, 65 litres of water being carried in a radiator and a circulating system which weighs 83 kilogrammes complete. In "working order" the total weight, everything included, represents 5 kilogrammes per horse-power.

The engine runs at 1050 revolutions per minute, but by means of a reducing-system of two gear wheels, the propeller shaft does not make more than a third of this speed—350 revolutions per minute. The fuel consumption is from 38 to 40 litres per hour; of oil about 5 litres. The whole of the motor is mounted upon a body, fixed to the car by springs in such a manner that vibration is reduced to the minimum, being no greater than in a well-built motor-car standing still with the motor running. The connection by circular segments is fitted with springs which can be easily regulated by means of a worm wheel so as to obtain a constant and absolutely certain tension. Lastly, we may add that the motor is fitted with two ignitions, magneto and accumulators, and that by means of decompression cocks it can be started up with the greatest ease.

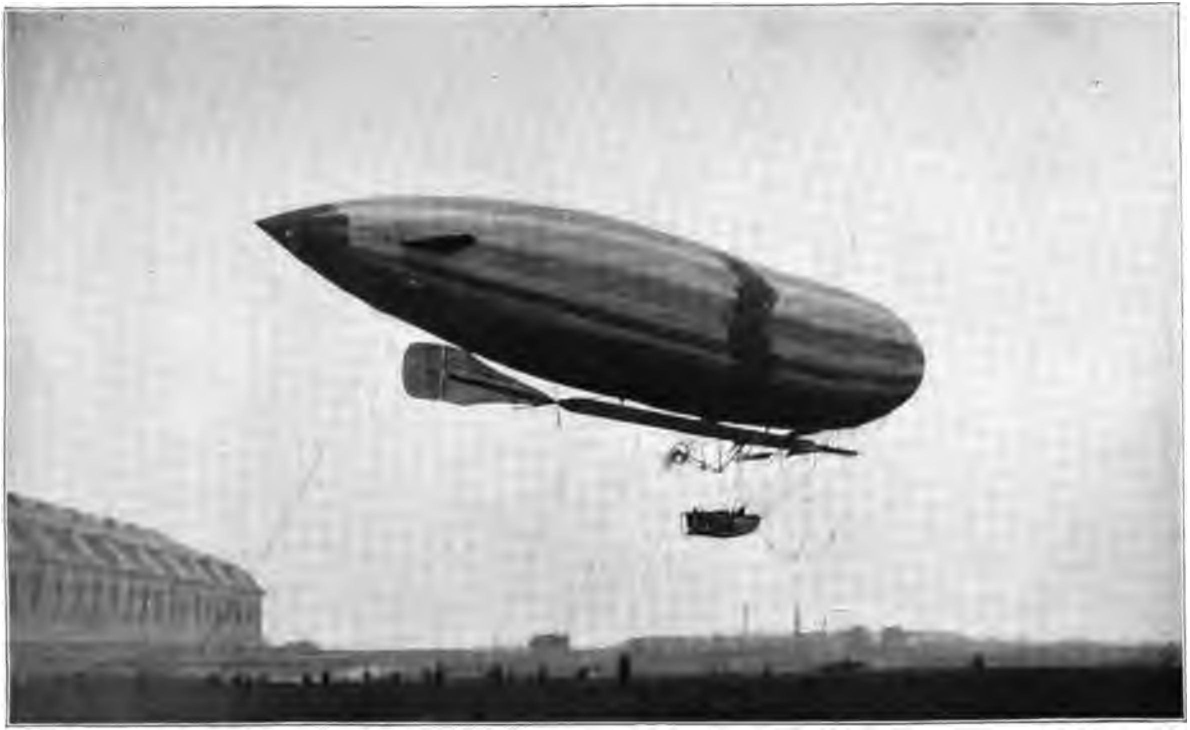
THE SCREW, "SLIP," DIMENSIONS, AND POSITION

The screw is the propeller exclusively used to-day in aerial navigation, both upon dirigibles and aeroplanes. As a matter of fact, the screw constitutes to the fullest degree the first and most important acquisition; simple, and when its design, dimensions, and its operation are well thought out, its performance is excellent.

It is scarcely necessary to explain a propeller: it is a *screw*, or rather, there are two elements of the threads of this screw called the *wings* or *blades* which screw into the air. If the screw were to be driven into wood or a metal nut, it would advance a certain distance with each revolution. This advance would be always the same, and is known as the "pitch," which is simply the distance separating two consecutive threads, this distance being computed parallel to the axis. But the propeller of an airship screws into the air, and the latter is an unsteady nut, so that with each revolution the aerial vessel, instead of advancing a distance equal to the "pitch," only moves forward a part thereof. The difference between the "pitch" of the screw and the advance of the airship itself for each of these revolutions, is defined as the *slip* of the propellers, that is the proportion of this difference and the "pitch" itself. Thus a screw may have a slip of $\frac{3}{10}$ if, when it makes a revolution, the airship which it drives does not move forward more than $\frac{7}{10}$ of the pitch of the propeller.

This knowledge of slip enables us to consider the controversial question of large screws turning slowly, or of small screws revolving very rapidly, and we may understand readily that it is necessary, *à priori*, to reject the screws which are too small. Turning very rapidly they would drive away the immediately surrounding air without forcing the airship forward; their enormous slip would not enable it to advance. It is as Colonel Renard expressed in a picturesque manner by saying, "We cannot propel an Atlantic liner by rowing, even very rapidly, with a penholder." Let us therefore take screws of large diameter. But then again one is limited in their dimensions by considerations of weight. As they turn powerfully but slowly, it is necessary to add to their individual

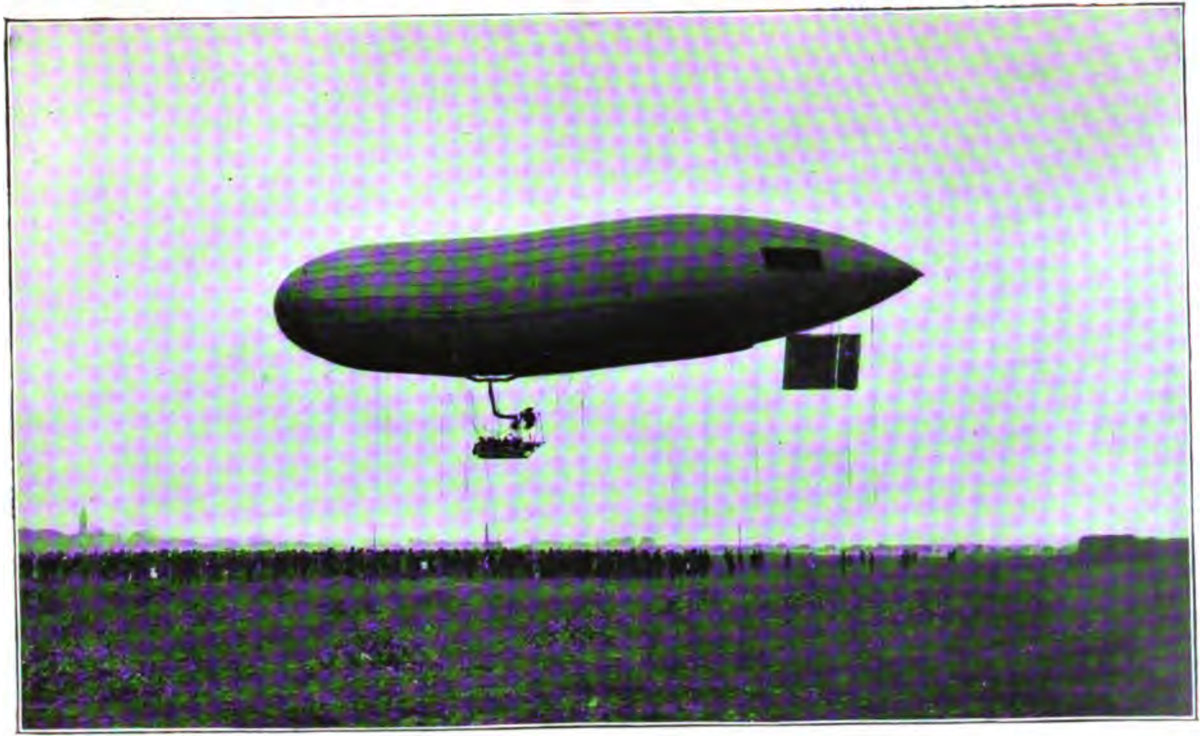
PLATE XIII



Photo, Rol

THE "PARSEVAL" FLEXIBLE AIRSHIP WITH TWO COMPENSATING BALLONETS

PLATE XIV



THE "GROSS" SEMI-RIGID AIRSHIP

Photo, Rol

weight that of the speed-reducing gear, which transmits the always very rapid revolutions of the light motors used in aerostation. Consequently there will be an absolute limit to bear in mind, because it is necessary to choose between the efficiency of the propeller, that is to say the portion of motor effort which is transformed into useful tractive effort, and the engine-power. By augmenting the weight of the screws the efficiency of the propeller may be improved; but then it becomes necessary to increase the weight of the motor, and it must not be forgotten that in aeronautics the question of weight is always vital, and that in an airship only a total given weight is available for the whole of its mechanical equipment, motor and propeller.

One other question now remains—the position of the propeller. Should it be placed at the prow, at the stern, or amidships? We have discussed this question already (p. 32) as well as that of determining the level at which it must be driven between the axes of the balloon and the car respectively.

These principles being disposed of we will consider the propeller of the *Clément-Bayard.*

Hitherto the screws of dirigibles have been made of sheets of light metal, bent and riveted upon metal frames; sometimes they were made of fabric stretched over a clumsy skeleton. The terrible disaster to the dirigible *République* was attributable to one blade of the propeller so constructed being wrenched off the shaft by the centrifugal force, and, perforating the envelope, precipitated the vessel to the ground with its passengers. This accident demonstrated the urgent necessity for making the propeller absolutely solid. And experience has shown that *wooden* propellers, with the blades having the grain of the wood longitudinally, are the most satisfactory. The screw of the *Clément-Bayard* is of wood, and is a striking piece of work by Chauvière the engineer.

It has only two blades; as a matter of fact if the number of the latter were increased too greatly, each would move in air already displaced by its neighbour, and efficiency would be decreased. M. Chauvière thought it possible, by special arrangements, to balance the efforts of propulsion and the effects of centrifugal force arising from the rotary movement, efforts and effects which increase in a general manner pretty well in accordance with the same laws.

The *Clément-Bayard* propeller is 5 metres in diameter. The pitch is variable and increases from the axis to the tips of the blades. It is built up of countersunk ribs assembled and superposed in the form of a fan, similar to the steps of a "winding staircase." Revolving at 350 revolutions per minute, each of the tips of the blades describes, in a circular path, 100 metres per second. This enormous "peripheral speed" is the maximum that has been attained so far with screws of this design. At this speed it produces stabilisating effects, called *gyroscopic*, recalling to mind those of the small device used as a toy known as the *gyroscope*, the stability of which, occasionally, is disconcerting. It seems to defy the laws of balance by maintaining simultaneously its rotating speed and the mass disposed around its circumference. In the case of the actual propeller its gyroscopic effects oppose strongly the pitching of the balloon, and therefore produce a stabilisating effect. This was the reason why the constructor did not strive too much after lightness in designing the propeller, which weighs 90 kilogrammes.

At speeds of 350 revolutions per minute the *Clément-Bayard* propeller sustains with its blades a centrifugal effort exceeding 19,000 kilogrammes, and yet so perfect is its construction that it is not submitted to more than one-twentieth of its breaking strain.

The independent speed of the balloon, driven by its motor and propeller, is 50 kilometres per hour; *i.e.*, 14 metres per second. To complete our description let us add that the dirigible is always berthed in a shed which enables it to await, sheltered from heavy weather, favourable conditions for pending journeys. The first shed was erected at Sartrouville, but a new shelter has been built near Meaux.

HANDLING THE AIRSHIP : STARTING OUT : *EN ROUTE* : THE DESCENT

The handling of a dirigible balloon is not so simple as that of a spherical balloon owing to the elongated form of the envelope containing the gas, upon which depends the ascensional effort.

First the dirigible must be brought out of its shed wherein it is held upon the ground by a considerable, imposed weight, comprising bags of ballast. A number of men draw up in two lines on either side of the balloon, in which the pilot and his assistant take their places. The men detach the ballast-bags carefully until the balloon evinces a very slight tendency to lift. Hauling with all their might, they bring it out of its dock, so holding it that it almost touches the ground. Arriving in the open air, it is hauled to as level an area as possible, and then again loaded with the bags of ballast, so that it rests naturally upon the ground.

The pilot assures himself that all is in good order; that the valves work, that the cords which control them are to hand, are not twisted or swollen; that the recording instruments work properly; that the wheels of the steering rudder and stabilisator efficiently govern those two mechanisms; that his compass, his charts, his ballast are all to hand, as well as the cord which operates the ripping valve. Meantime the engineer has passed as minutely over his motor, seeing to the lubrication of all parts, the propeller shaft and bearings; tests his indicators and recording instruments, and then when all is ready informs the pilot.

The latter now instructs the men to swing the balloon round in such a way that it starts out "to leeward." The passengers embark, and the ballast is discharged little by little, until the balloon rises slightly; this operation is called "weighing" the balloon. The pilot commands the engineer to start up the motor, but without coupling-in the propeller. When the engine is under way and all is ready, the navigator throws out the last bags of ballast so as to give the balloon the requisite lifting effort. "Hands off," he shouts. At this command the workmen release the sides of the car to which they have been clinging, and the balloon is now held by two ropes only, attached to the under side of the car by a "goose-foot" at front and rear respectively. These cords are then "paid out" equally, in such a manner as to keep the airship horizontal. When at last the pilot cries "Let go," the men drop these ropes and the vessel rises. The pilot orders the engineer to let in the propeller; the balloon attains its independent speed, and with a turn to make sure the steering mechanism is working properly, the pilot sets the course it is proposed to take.

En route, if the weather is clear, the pilot always keeps his eye upon the chart, so as to assure himself that he is following the right course by comparison with the actual topography of the country unrolled beneath the feet of the travellers. If he ventures out at night, or in a fog, he will fix his attention upon the compass, while his assistant at the wheel of the stabilisator will not let his eye leave the barometer, so as to preserve by the manipulation of the elevator, the desired altitude of the balloon, without discarding ballast or letting out gas.

With regard to the sensation of "wind" felt by travellers, this is only due to the independent speed of the balloon, 45 to 50 kilometres per hour. Whether it be a following, or a head, wind it will always be the same, neither more nor less intense, because the "surrounding" wind does nothing but carry the whole of the atmosphere, of which the balloon is a part, from one point of the earth to another. Travellers in the car are under the same conditions as if they ran very quickly to and fro through the saloon of a large liner. The speed of their movement creates an impression of wind which is the same, irrespective of the direction and force of the wind, which blowing over the surface of the sea transports, in a combined movement, both them and the vessel in which they are sheltered.

So far as concerns ascent and descent, this is effected within a small limit, about 100 metres, by the aid of the stabilisator. It must be pointed out that, unlike the free balloon, the ascensional effort of an airship is constantly increasing. Unballasting is continuously taking place through the consumption of the petrol by the motor, and in this manner it loses about 40 kilogrammes per hour. This is where the charging of the air ballonnet intervenes fortunately to secure the constancy of the external shape and consequently also the persistence of the air pressure.

It is scarcely necessary to urge passengers in a dirigible to exercise the greatest prudence. *Nothing must be thrown overboard*, be it a bottle, an empty box, or even a chicken bone, without the pilot's permission: the static sensibility of these airships is extreme, and it is necessary to avoid any action which might vary it accidentally.

As to the descent of an airship, at least in the majority of cases, it must take place only in the vicinity of a shed, descent in open country being always hazardous. This was only too well shown in the accidents to the *Patrie* and the *Zeppelin* airships. Landing is made in a manner just opposite to that of ascent. But care must be observed that the men who seize the two guide-ropes to bring the balloon gently to earth at first grasp the "windward" rope so as to hold the balloon with its nose to the wind. Negligence of this precaution, and the balloon, held only by the stern rope, will rear up, owing to

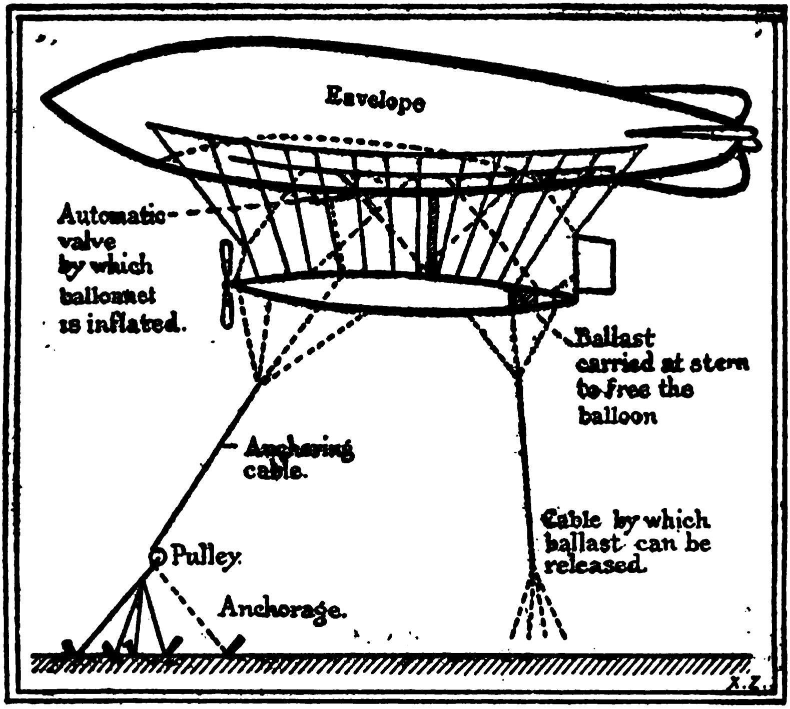

Envelope
Automatic-valve by which ballonnet is inflated.
Ballast carried at stern to free the balloon
Anchoring cable.
Cable by which ballast can be released.
Pulley.
Anchorage.
X.Z.

FIG. 25. Constructor Surcouf's method of mooring a dirigible

The vessel swings itself nose to the wind, and the latter keeps the ballonnet inflated automatically the wind driving against the prow, and thus imperil it. Once the balloon has landed the workmen seize it by the car, load it with bags of ballast, and then bear it gently into its shed.

However, the airship might reach, be compelled to descend, and to "moor" by the aid of its anchors in open country. In such a case there is an arrangement conceived by M. Surcouf which appears to offer the greatest security to an airship forced to make a "halt" at a place unprovided with a special shelter.

Beneath the body, and towards the front of the balloon leading to the ballonnet, is an automatic valve (Fig. 25) which opens like a purse. During the journey a spring keeps it closed, and the ballonnet works as usual by means of its charging fan. But if the vessel is compelled to stop, it is fixed to the ground by anchors, or by stakes and cable, which by means of a "goose-foot" is attached to the prow of the car, the balloon thus being held stationary, with its motor stopped, swinging in the wind. But under the influence of temperature fluctuations the gas will contract or expand, and with the motor no longer running, the ballonnet will not be able to maintain the invariable form of the envelope.

Then, under the pulling action of the restraining cords, the "mooring" valve opens, always to the wind, since it is to the front of the balloon, which adapts itself like a weather vane, nose to the wind. Under these conditions the air so caught in the pocket forces the valve open, and thus keeps the ballonnet inflated to assure the permanency of its shape. One can, for greater security, attach bags of ballast to the stern rope. If the stern of the balloon should descend this ballast would strike the ground, and the envelope, released of a considerable weight, would rise again before it could come into contact with the earth and be damaged thereby.

VOYAGES OF THE "CLÉMENT-BAYARD"

The dirigible balloon which we have described in detail has completed more than thirty trips, with uniform success. During the Aeronautical Show held at the Grand Palais in the month of December 1908, it came and hovered above the Champs-Élysees repeatedly. Its evolutions over Paris have rendered it popular, familiarising every one with the appearance and travel of an airship. It has made numerous cruises around the capital, some very lengthy, but all brilliant, first under the direction of M. Kapférer, collaborator of M. Surcouf; later of M. Capazza, the eminent Corsican aeronaut, who so far has been the only man to cross the Mediterranean in a balloon.

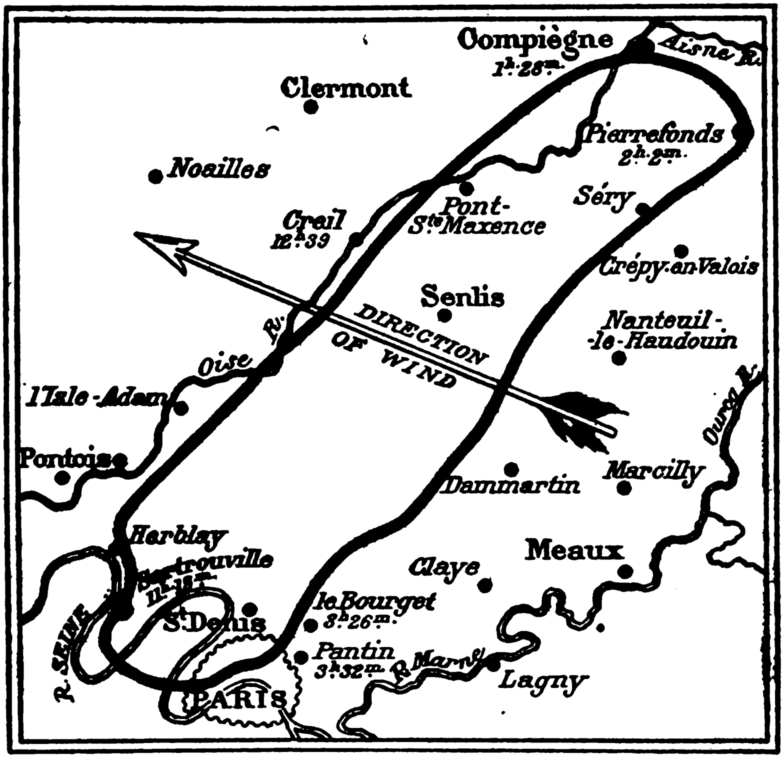


FIG. 26. Voyage of the *Clément-Bayard* (Nov. 1908)

250 *kilometres in a complete circuit in five hours, without descent*

The most remarkable of these excursions was that when M. Clément resolved to set out from the airship shed to visit his seat at Pierrefonds (Fig. 26). The vessel left Sartrouville on November 1 at 11.15 A.M. in an east-south-east wind blowing at a velocity of 20 kilometres per hour. M. Clément, the owner of the balloon, was accompanied by a passenger; MM. Capazza and Kapférer were on the bridge; Sabathier the engineer, and a mechanician, were at the motor. The balloon passed successively over Maisons-Lafitte, Pierrelaye, l'Isle-Adam, Beaumont, Creil (at 12.39), Pont Sainte-Maxence, Compiègne (at 1.28). It then wore round to the east and arrived at Pierrefonds at two o'clock; thence it resumed its journey to Paris, by Rocquemont, Ermenonville, Chennevières, Bourget (passed at 3.26), Pantin, described a large circular sweep over Paris, and regained Sartrouville at eight minutes past four. The total distance was 250 kilometres, and it was covered in 4 hours 53 minutes. It was a remarkable record for *a round trip* accomplished by a dirigible without descent during its journey, and returning to its starting-point. The great journey of the *Zeppelin* described in the following chapter was not completed by return to the point of departure, inasmuch as the airship was destroyed unfortunately in the course of its homeward journey.

Finally we may mention that in August 1909 the *Clément-Bayard* made a noteworthy journey with a commission of Russian officers aboard. The latter had been sent to France to investigate aeronautics for the purpose of facilitating the creation of a Russian aerial fleet. The airship was piloted by M. Capazza, who navigated the craft to an altitude of *1550 metres!* Such a height had never been gained previously by any dirigible.

The official carrying capacity of this airship is as follows: 6 passengers, 300 litres of fuel, 20 litres of oil, 65 litres of water, 250 kilogrammes of ballast (sand in bags), and 59 kilogrammes of manœuvring ropes.

"AERIAL YACHTS"

Such a dirigible as we have described is, in the realm of aerial navigation, the equivalent of a warship, or of a large mercantile steamship; it is the "ocean liner." But its great cost (about £12,000), the absolute necessity of maintaining an immense and expensive shed, renders it a vessel of pleasure impossible to many amateurs for aerial trips. A "little dirigible," an "aerial yacht" at a more popular price, and more simple to control, was demanded. Such a convenient type of small balloon is now available, and is known under the generic name of the "Zodiac."

This, to hazard a comparison borrowed from automobilism, is the "aerial voiturette." It is designed to enable one or two passengers to make jaunts into the air, and without the necessity of maintaining a sheltering shed.

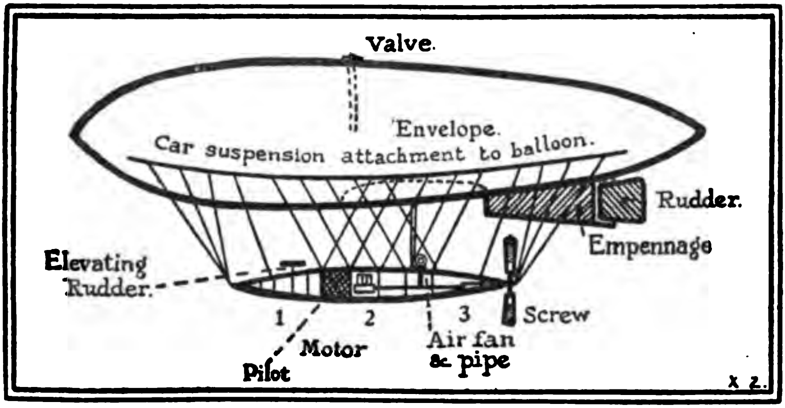


Fig. 27. A little "Zodiac" dirigible

For this purpose the gas bag, of 700 cubic metres, is inflated, not with pure hydrogen, which is expensive and not always obtainable, but with coal gas, which is available at all towns and can be purchased cheaply. Inflated therewith it will lift one person, but by combining coal gas with about 100 cubic metres of hydrogen, it will lift two people. It is pisciform in shape, with stabilisating planes, and has two rudders.

The car is detachable into three pieces; each of the latter is formed of wooden trellis, light, flexible, and yet at the same time solid, the sections being fitted together by bronze sockets, nuts, and bolts. A water-cooled, four-cylinder, 16 horse-power motor drives through cardan shafting a stern propeller, which runs at about 600 revolutions per minute. The latter is of 2·30 metres diameter. The motor also actuates a fan which, through the medium of an air-ballonnet, maintains the permanent external form of the envelope.

The whole balloon dismantled, motor, car and envelope, packed in canvas cloth, can be transported by horse and cart. The balloon is inflated at the point where the gas is obtainable, and it can be prepared for an ascent in an hour and a half. This little airship can travel at a speed ranging from 25 to 28 kilometres per hour; can remain aloft for three hours with 75 kilogrammes of ballast; and costs, ready for use, £1000. Truly therefore it is the aerial "auto," enabling trips to be made into the air without being compelled to return to a stationary shed, because the balloon coming to earth at the end of its journey can be deflated like a simple "spherical" and be loaded upon a cart for conveyance to the nearest railway station.

This handy type of little dirigible certainly fulfils in every respect the "popular airship." On Easter Sunday, April 11, 1909, it made a remarkable journey. With MM. Henry de la Vaulx and Clerget on board, it manœuvred above the Bois de Boulogne for three hours with the greatest ease, before the eyes of crowds of Parisians, which the beautiful weather had caused to flock upon their favourite promenade.

During the summer of 1909 another vessel of this type, *Zodiac III.*, slightly larger than the above (1400 cubic metres capacity), was utilised on a hunting trip by Comte de la Vaulx and M. André Schelcher. Furthermore, it carried out a number of remarkable ascents at Brescia and in Belgium, demonstrating its handiness, convenience, possibilities, and facilities, in regard to inflation and deflation.

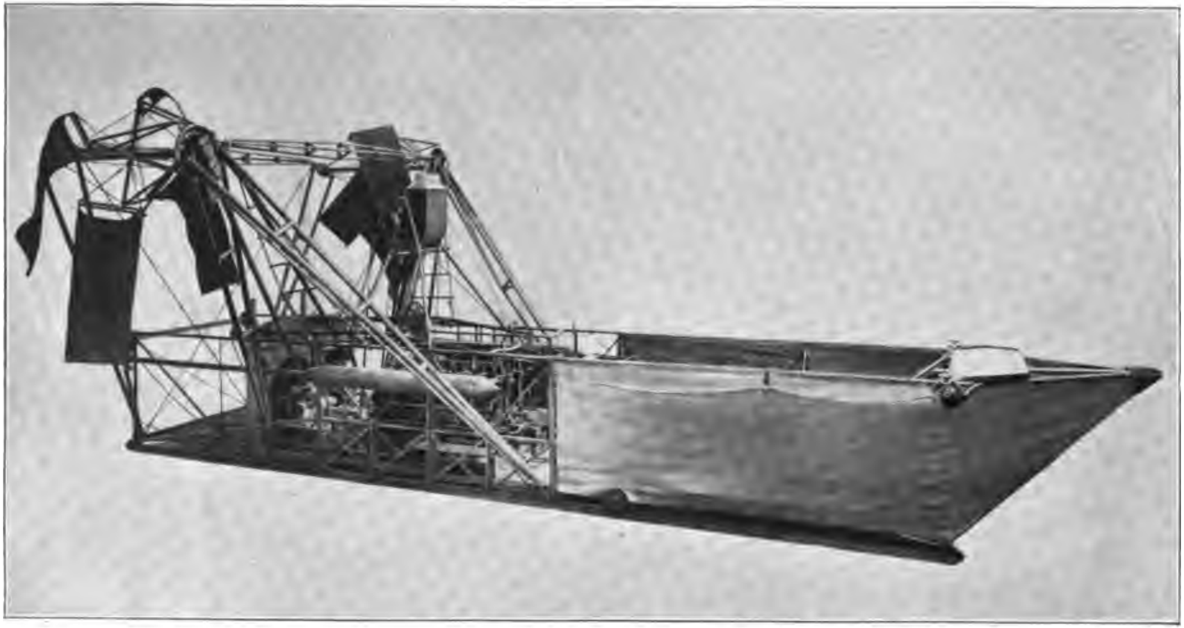
An airship of this type, but of 2000 cubic metres capacity, was presented to the French Government by the subscribers to *Le Temps* fund, after the disaster to the *République*. This craft is now employed for the training of aerial pilots at the French Military Training College.

IMPRESSIONS IN A DIRIGIBLE : DIZZINESS : SAFETY

Now, questions which arise naturally in the mind of the reader, and asked of all who have travelled in a dirigible, are, What are the sensations? Does one suffer from giddiness? Has one sea-sickness? Has one fear?

I will endeavour to reply to these interrogations.

PLATE XV



THE CAR OF THE "PARSEVAL,"
Showing blades of propellers, which fold over when at rest

PLATE XVI

"A GERMAN RESERVE"
Stacks of Hydrogen Cylinders at the Gas Generation Station

On board an airship one has a feeling of complete security. Before entering the car there is time to take a walk round the balloon, for it is still berthed in its shed; to examine with care every part; to feel the lifting and suspension system. The whole is so solid; is made of material of such perfect quality; the total resistance is so well calculated and tested to twenty times what the whole will have to withstand, that in an instant every qualm of disquietude slips from the mind. The only hesitation one has is that of actually embarking. But the disasters to the Pax and the Bradsky balloons have been instructive. To-day the general utilisation of the air ballonnet secures stability; the motor is placed well away from the balloon; the suspension system is indeformable and distributes the weight equally over the envelope; all parts of the motor capable of giving off either sparks or leakages of gas are boxed in or covered with metallic sheathing. Lastly, trained and experienced aeronauts always conduct the ascents, for no owner of an airship would be mad enough to attempt a trip without the indispensable assistance of one of those "captains of the air," such as the Comte de la Vaulx, Capazza, or Kapférer, for example.

Mal-de-mer is unknown aboard these airships, for the simple reason that the longitudinal stability being so very great there is neither pitching nor rolling. Many ladies have received the baptism of the air; and not one has suffered from this terrible malady of which ocean vessels preserve, alas! the unenviable monopoly.

With regard to dizziness, this is unknown in a balloon when the latter is not held to the earth by a rope. Giddiness is produced when looking from the top of a tower, or the edge of a precipice, by the view of the vertical wall which drops below one's self, and which "conducting the eye" right down to the bottom, enables one to calculate the depth of the chasm. In the captive balloon the sight of the cable may sometimes produce the same effect; but in a dirigible, there being no material connection, one cannot estimate one's altitude. One believes, and one actually is, above a magnificent plan in relief; with a feeling of beatitude which is grand; with the impression indeed of being independent of all; to have broken away from one's bonds and to be the master of space.

Consequently it is now possible to accomplish voyages by dirigible in the strictest sense of the word, and in absolute safety. I have made many myself, which I shall never forget, on board the *Clément-Bayard.* The time is not far distant when airships, in addition to their military utilisation, of which we will speak after we have described aviation apparatuses, will have applications to everyday life, without speaking of their employment in those geographical explorations which yet remain to be made.

CHAPTER V

HISTORY AND DESCRIPTION OF THE PRINCIPAL DIRIGIBLES

EARLY DAYS OF AERONAUTICS: FROM GENERAL MEUSNIER TO COLONEL RENARD, GIFFARD, DUPUY DE LÔME, TISSANDIER: M. HENRY DEUTSCH, COUNT ZEPPELIN, M. SANTOS-DUMONT AND M. LEBAUDY

THE PIONEER: GENERAL MEUSNIER, INVENTOR OF THE AERIAL PROPELLER

THE history of dirigible balloons, up to recent times, has been somewhat devoid of results. If the importance of what has been done is unquestionable, it can be asserted at least that the quality in this case substitutes quantity, since it was no farther back than 1852 that the first serious attempt in this direction was made by Henry Giffard. Before him there may have been some ideas more or less vague, but nothing tangible.

However, it is one of these projects which it is necessary to describe, and that with some detail, because of its importance, its far-reaching value, and the date of its conception. It is that made in 1784, scarcely one year after the discovery by the brothers Montgolfier, by an engineering officer—Lieutenant, subsequently, General Meusnier.

Meusnier was a prodigy. He astonished his masters by his precocity, by the confidence of his reasoning, and by the perspicacity of his views. He was made a member of the Académie des Sciences at twenty-nine, on account of his work in aerostation, which however was only one of his accomplishments, for he was the collaborator of Lavoisier in several experiments. He was killed at the siege of Mayence in 1793; he was then General.

Meusnier was the true inventor of aerial navigation, and was a "scientific" initiator. Through not following the lines which he laid down, aerial navigation lost a century groping about fatuously; in conducting experiments absolutely without method. In fact, at a time when relatively nothing was known concerning the science of the atmosphere, Meusnier had the distinction of elaborating all the laws governing the stability of an airship, and calculating the conditions of equilibrium for an elongated balloon, after having demonstrated strikingly the necessity of such elongation. Meusnier's designs and calculations are preserved in the technical engineering section at the French War Office in the form of drawings and mathematical formulæ.

His airship designs relate to two balloons, one very large, the other much smaller, and it is in these projects that one finds described distinctly two absolutely new arrangements which are in universal use to-day: the *air-ballonnet* to secure stability and the *screw* for aerial propulsion. With regard to the motive power, owing to the absence of suitable motors in his day, he contented himself with the use of the muscular power of the men carried on board.

The dimensions of his largest balloon (which, however, was never constructed) were 260 feet in length, and 130 feet in diameter; that is to say 85 and 42·50 metres respectively. The shape was that of an ellipse, and as one may see, the elongation was equal to twice the diameter. The cubical contents were to be 60,000 cubic metres.

Thus the balloon (Fig. 28) would have followed the form of a perfect ellipsoid, which was the paramount development to be realised as compared with the spherical form. It was to be a double envelope, comprising two skins, each of which was to fulfil a distinct purpose. The first, the "envelope of strength," very resistant, was consolidated by bands. The second, placed within the former, was to be impermeable to the light gas which was to sustain it. This inner balloon was never to be inflated fully, and the space between the two envelopes was to receive, in varying quantities, the air to be forced thereinto through pipes by two pumps carried in the car. This was in very truth the *air-ballonnet*, and its use without doubt was to maintain invariability of the external shape.

The car was to be attached to the envelopes by a triangular suspension system. This was the "indeformable suspension" which to-day is considered imperative, and which is adopted universally. The lifting system was to be attached not to a net, but to a *girth* sewn to the fabric. Moreover, at three points where the lifting rope members met, forming "suspension knots," the axes of the three propellers were fitted, which Meusnier described as "revolving oars" (*rames tournantes*) and which were no other than screw propellers. Consequently this remarkable system, which is now used for driving steamships, was invented in 1784 for aerial navigation and by a Frenchman at that. But that was not all. Meusnier not only recommended the elongated form; not only conceived

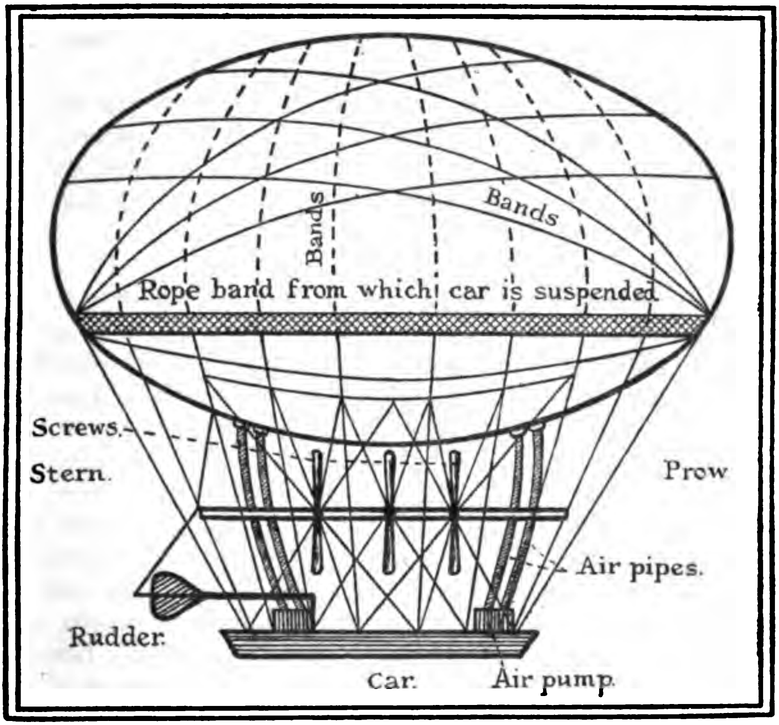


FIG. 28. The first dirigible, designed by General Meusnier (1784)

the girth fastening; the triangular suspension; the air ballonnet; and screw propeller; but moreover indicated the point at which the last-named should be installed. It may be observed in the diagram that the motor shaft is not connected to the car, but is placed between the latter and the balloon. In this way the illustrious and accomplished officer laid down everything requisite for aerial navigation. For this reason he deserves justly the distinction of being the forerunner, the initiator, of aeronautics.

We are indebted for this information to a remarkable memoir of the engineering lieutenant Létourné, which was presented to the Académie des Sciences by General Perrier in 1886, wherein these details are set forth in a very scientific manner.

THE FIRST MOTOR BALLOON: GIFFARD'S AIRSHIP (1852)

It was some sixty years later that the problem was first resolved practically, by an eminent engineer whose name is justly celebrated—Henry Giffard, the inventor of the "Giffard injector," used throughout the world in connection with the boilers of locomotives. Giffard was convinced of the impotency of the "human motor," and its excessive weight, and he conceived the bold idea of carrying a steam-engine complete with boiler and propeller under an elongated balloon. One shudders in thinking of the courage of this man who ventured to carry an incandescent fire immediately beneath his balloon inflated with hydrogen. But the many precautions which he adopted ensured him of safety.

The shape of his balloon was of a symmetrical cigar, pointed at both ends (Fig. 29). Its length was 44 metres, diameter 12 metres, the elongation thus being in the proportion of 3·5 to 1. Its volume was 2500 cubic metres, and it was inflated with coal-gas which gave him a lifting power of 1200 kilogrammes. The steam-engine, including boiler, weighed 159 kilogrammes, and developed 3 horse-power, giving a weight of 53 kilogrammes per horse-power. It was at that time a noteworthy achievement. The engine was inverted, to reduce the risks from fire, and was mounted on a platform attached by six ropes to a "strengthened beam" supported by slings connected to a net which covered the whole of the balloon except on its under side. This suspension, one can see, had the drawback of being possible of displacement. Moreover, the absence of the ballonnet did not secure permanence of the envelope's exterior form. On the other hand, the use of the long pole had the advantage of distributing the strain upon the whole of the aerostatic envelope in a pretty uniform manner. At the stern a triangular sail, manœuvred from the car, formed the rudder.

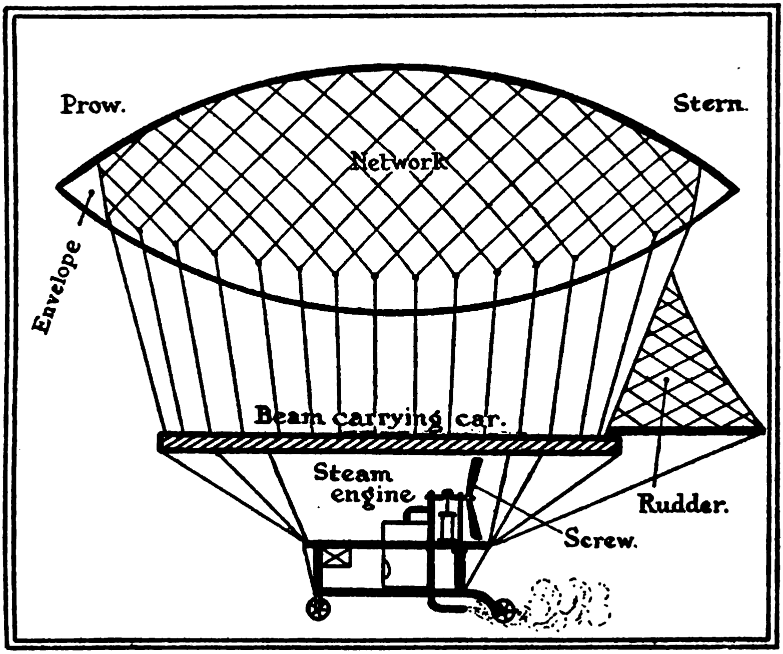


FIG. 29. Henry Giffard's steam-driven balloon (1852)

Though this vessel never accomplished a complete circuit, yet it was able to deviate from the direction of the wind, and demonstrated the "possibility" of steering balloons

With this balloon Giffard carried out some experiments of the greatest value. True, the low independent speed (3 metres per second) which he obtained, in conformity with his calculations, did not permit him to describe a circle in the air: but he was able to make some very neat evolutions, deviating at his desire from the direction of the wind, thereby testifying to the efficiency of his rudder. In a word, he succeeded in demonstrating, in an experimental and unquestionable manner, the possibility of aerial navigation by the aid of an airship furnished with a motor and a screw. Consequently, his efforts belong rightly to the history of aeronautics.

DUPUY DE LÔME'S DIRIGIBLE (1872)

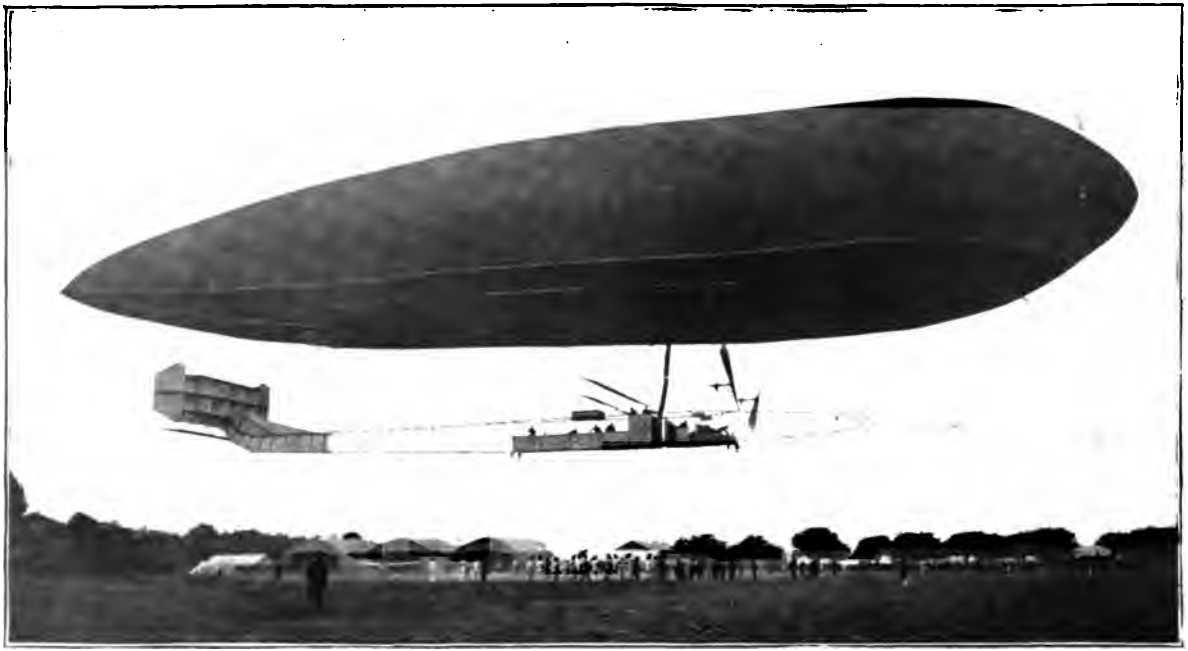
It is necessary to wait another twenty years to see a second rational effort in aerial navigation. This was made by the illustrious marine engineer, Dupuy de Lôme, the inventor of the ironclad. Struck with the value of balloons during the siege of Paris, Dupuy de Lôme thought that this utility could be doubled if one were able, not only to leave the besieged capital as did the free balloons, but to return again at will! So he set to work to perfect a dirigible free from the disadvantages of Giffard's.

Notwithstanding the excessive weight of the human motor, he decided to rely upon the muscular energy of the passengers to move his screw, so as to avoid the dangers of the steam-engine. The balloon was fusiform, symmetrical, and pointed at both ends. Its length was 36·50 metres, diameter 14·84 metres, giving an elongation equivalent to 2·5. The volume of the envelope was 3450 cubic metres.

In the interior of the latter was placed an *air-ballonnet;* this, in short, was the first time that Meusnier's conception was acted upon. The volume of this ballonnet was a tenth of that of the balloon. But Dupuy de Lôme did not pin his faith, in the use of the ballonnet, to the lines set forth by General Meusnier. He adopted the indeformable triangular network suspension. The screw weighed 75 kilogrammes, was 9 metres in diameter, and was driven by eight men. Under these conditions the stability was perfect, and in still air the balloon was able to travel at a speed of 2·25 metres per second—very nearly 8 kilometres per hour.

Conceived and designed during the siege of Paris, the balloon was not built until 1872. It did no more than start at Vincennes, on February 2, 1872. Notwithstanding a violent

PLATE XVII

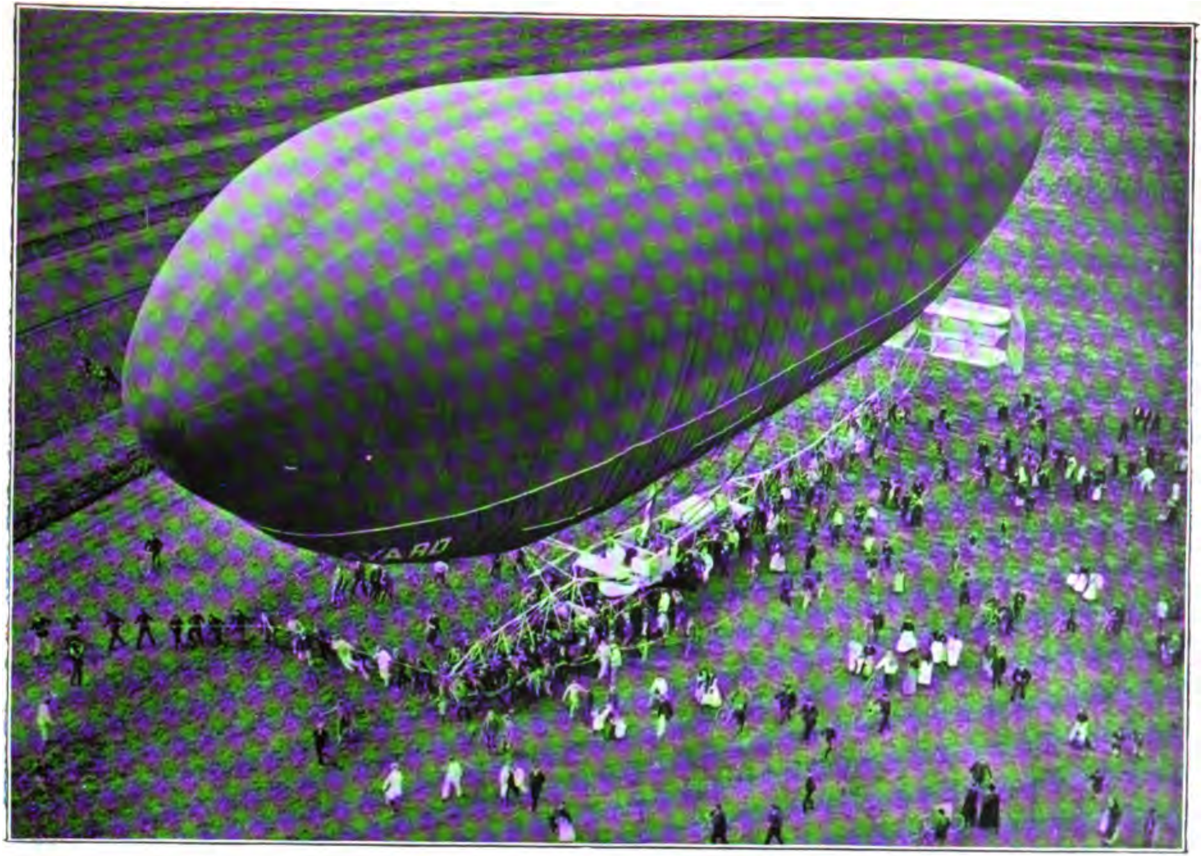


"CLÉMENT-BAYARD NO. 2"

Photo, Branger

The ballonet empennage is abandoned in favour of a series of "cells" fixed to the stern slightly above the car. The airship is driven by two screws

PLATE XVIII



THE "CLÉMENT-BAYARD NO. 2" LANDING

wind, the stability was perfect, owing to the triangular suspension, and the airship was able to deviate 12 degrees from the wind's direction. This test had the merit of defining the essential points for the construction of dirigibles, and to show the possibility of obtaining, while travelling, an absolutely perfect stability.

DIRIGIBLE BALLOON OF THE BROTHERS TISSANDIER (1883)

Impressed by the qualities and regular working of the electric motor, and the absence of danger which attended its use, MM. Albert and Gaston Tissandier in 1883 built a dirigible airship driven by an electric motor, for which the energy was supplied from a bichromate of potash pile battery.

The balloon was fusiform, symmetrical, with the two ends pointed, and having an elongation equal to 3; its length was 28 metres, greatest diameter 9·2 metres, and its volume 1060 cubic metres. The netting, the cords and the knots of which, by their projection, offered such resistance to movement, were replaced by a suspension "cover." The very light screw weighed no more than 7 kilogrammes, and was set 10 metres from the balloon.

The motor (a Siemens dynamo) weighed 55 kilogrammes for a motive effort of 1½ horse-power; electricity was furnished by four batteries, of which each comprised six compartments, each forming a pile element. The reservoirs, raised or lowered at will by a system of pulleys, connected or disconnected the liquid exciter, which was an acid solution of bichromate of potash.

After a preliminary trip in October 1883, the balloon sailed for so long as two hours at an independent speed of 4 metres per second, in September 1884: it was not able to go against the wind, but was able to complete numerous evolutions to the right or left of the direction of the latter. Stability was defective, owing to the absence of the ballonnet.

Be that as it may, the Tissandier balloon was the first dirigible driven by electricity; it opened a way which could be followed, and which might lead towards the definite solution of the problem of aerial navigation.

CAPTAINS RENARD AND KREBS' BALLOON "LA FRANCE" (1884 AND 1885)

It was about this time that Captain Renard, director of the military aeronautical establishment at Chalais-Meudon, in collaboration with his brother, Captain Paul Renard, and Captain Krebs, built a vessel which combined in its new lines all indispensable features, and which realised all necessary requirements as much in the aerostatical as in the mechanical parts. This balloon is indisputably the starting-point of practical aerial navigation, and it has served as a model to all who have followed. Moreover, those who have digressed from the lessons furnished thereby have counted nothing else but failure.

This pisciform balloon (Fig. 30), with its larger end in front, was 51 metres long and 8·40 metres in maximum diameter, which represents an elongation equal to 6. Its volume was 1864 cubic metres. The envelope, of varnished Chinese silk, was built up of longitudinal gores converging towards the two points. The network was replaced by a "cover" formed of bands of transversal widths of silk sewn together at their edges, and so cut out as to follow the "geodesical lines" of the surface. The triangular suspension advocated by Dupuy de Lôme was discarded in favour of two oblique "cross-pieces" connecting with the front and rear of the car, and with the balloon cover suspension; those in the centre were parallel with them, and directly carried the car.

The vertical steering rudder was placed at the stern. It was a lath framework strengthened by two diagonals, and covered with a double sheathing of silk stretched to form its surface. At the rear of the car, moving about a horizontal axis, was an "elevating rudder" which inclined to the front or to the rear, enabling the balloon to be given an ascending or descending movement.

The design of the car was new entirely; its great length recalled the oar-propelled yawls used in regattas. It was built up of bamboo trellis, had a length of 32 metres by 1·30 metres broad, and a maximum depth of 1·80 metres. Its great length is copied to-day in the most successful dirigibles, such as the *Ville de Paris* and the *Clément-Bayard*. A "cabin," containing the motor and all necessary control, was placed forward.

The motor, built by M. Gramme, weighed 96 kilogrammes, and developed 9 horse-power. The energy was transmitted through a hollow shaft, the bearings of which were fixed to two flexible suspensions, to a screw placed at the *prow* of the vessel. This arrangement is likewise reproduced to-day in our most modern dirigibles. The screw was 7 metres in diameter, with a pitch of 8·50 metres, and weighed 40 kilogrammes: it made 50 revolutions per minute.

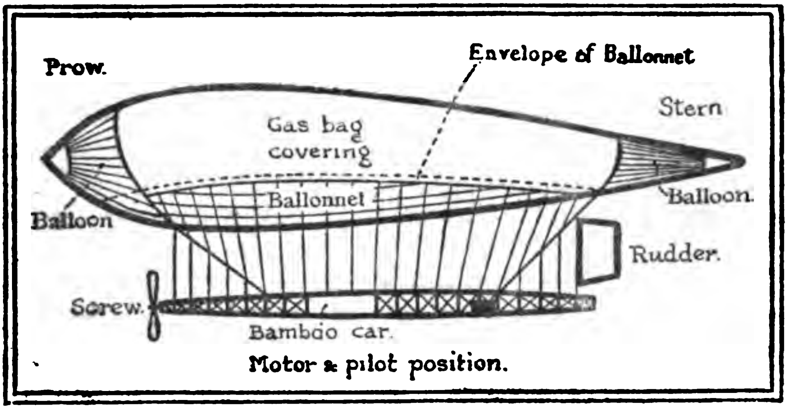


FIG. 30. The balloon *La France*, designed by Captains Renard and Krebs (1884)

The electrical generator comprised a "chromium chloride" battery invented by Colonel Renard and was of extreme lightness. Each element was formed of a glass tube in which was a very thin platinum-silver electrode, in the centre of which was a zinc rod. The total weight of this accumulator was 400 kilogrammes, which represented 44 kilogrammes per horse-power.

The independent speed of the airship with this power system was 6·50 metres per second.

The first ascent took place at Chalais on September 12, 1884. The balloon manœuvred with the greatest ease and returned under its own power to the starting-point. This was a decided triumph, echoed throughout the world. Three further ascents were made in the same year to tune up the apparatus. Then in September 1885 two historical ascents were held in the presence of General Campenon, Minister of War. *La France* left Chalais, described several evolutions *over Paris*, and returned to its *shed* under its own power: *the first round "aerial voyage" there and back was completed* (Fig. 31): aerial navigation became an accomplished fact, the "highway of the air" was opened and aeronauts only had to fly.

THE ERA OF THE "EXPLOSION" MOTOR: M. HENRY DEUTSCH: M. SANTOS-DUMONT'S EXPERIMENTS

The Chalais-Meudon balloon was consequently the marvel of its day, and undoubtedly with electric motors it was difficult to advance farther in this direction; but a new mechanical engine had appeared creating a new industry and revolutionising the art of transportation. This was the "petrol motor." One man contributed as much by his efforts and his personal action as by his generous encouragements to popularising its exclusive use for aerial navigation. This was M. Henry Deutsch de la Meurthe.

So soon as it was perfected he undertook the important task of showing the part the explosion motor was destined to fulfil. It was driven by that marvellous accumulator of energy—petroleum spirit. From his youth he had been consumed by one obsession—the solution of aerial navigation. When he saw what Colonel Renard had done by the use of the electrical motor, he conceived the idea of pressing the petrol engine into aeronautical service, and as far back as 1887 demonstrated to the officers of Meudon the possibilities there were in extending their efforts towards this end. At the same time he ordered the constructors Mignon and Rouart to build an explosion motor upon the new lines, and in 1889 showed President Carnot the first petrol motor-driven carriage. Always reverting to his idea of steering balloons, he accordingly undertook to furnish the financial and material means to demonstrate the possibilities of the petrol motor in connection with aerial navigation. After expending considerable sums in actual research, he unhesitatingly offered numerous prizes to encourage the efforts of aeronauts and aviators. The "Deutsch prize" of £4000 certainly contributed much to stimulate their enthusiasm, and it is only an act of justice and acknowledgment to place the name of M. Henry Deutsch at the forefront of contemporary aeronautical history, the many conquests in which are undoubtedly due to the exclusive use of explosion motors.

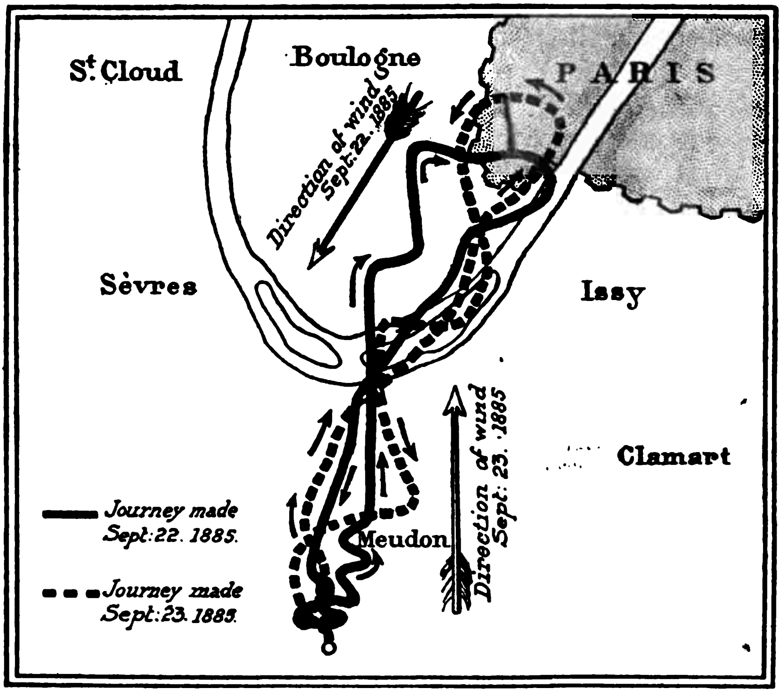

St. Cloud
Boulogne
PARIS
Direction of wind Sept. 22. 1885
Sèvres
Issy
Clamart
Direction of wind Sept: 23. 1885
Meudon
Journey made Sept: 22. 1885.
Journey made Sept: 23. 1885.

FIG. 31. The first two aerial voyages in a closed circuit made by *La France* over Paris in 1885

It was M. Santos-Dumont who, on October 19, 1901, won the Deutsch prize, the conditions of which consisted in setting out from St. Cloud, doubling the Eiffel Tower, and returning to the starting-point within half-an-hour (Fig. 32). With an indomitable perseverance, an unheard-of audacity carried to intrepidity, the young Brazilian aeronaut built dirigible after dirigible, some large, some small, some medium, and at last, after ten times escaping death narrowly, he succeeded in carrying off the much-coveted prize. His name became deservedly well known, more especially as a little later he lifted the first "Deutsch prize" for aviation. The airship with which he carried off the former trophy, the *Santos-Dumont No. 6,* had an elliptical envelope of 33 metres length by 6 metres diameter, and a volume of 622 cubic metres; there was an air-ballonnet of

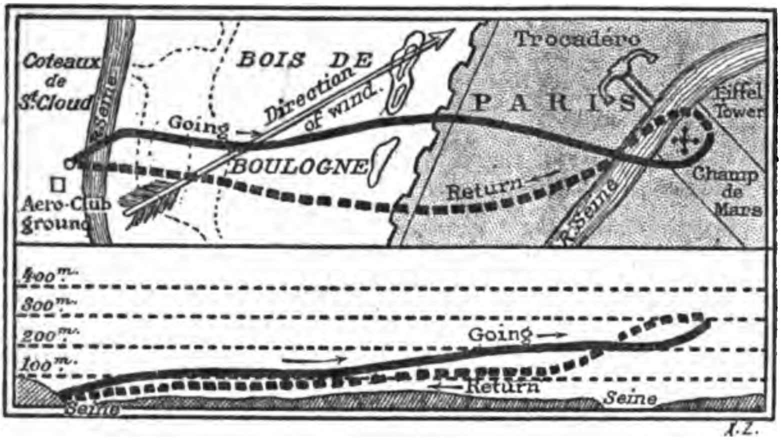


Fig. 32. Route and altitude map of Santos-Dumont's journey (Deutsch prize, October 1901)

60 cubic metres capacity, and his motor developed 16 horse-power.

Once the movement in favour of aerial navigation was started, it extended rapidly; on all sides surged inventors, not always alas! sufficiently proficient in theory or practice; not always prudent; not always profiting by the lessons given by their illustrious predecessors. The Brazilian Severo d'Albuquerque met his death in 1902 through his balloon exploding owing to the lack of foresight in the installation of the motor; in the course of the same year, 1902, the engineer Bradsky was killed, together with his companion Paul Morin, through the defective character of the suspension of the dirigible, which, notwithstanding Colonel Renard's recommendations, did not include the ballonnet.

THE "LEBAUDY" BALLOON. "LA PATRIE"

These catastrophes did not damp the ardour of aeronauts. But they made them more careful, and led them to realise the necessity there was for them to be grounded thoroughly in all questions touching aeronautics, if they desired to venture to build and test a dirigible. So in 1902, when MM. Lebaudy decided upon the construction of a huge airship, they secured the collaboration of a distinguished engineer, M. Juillot, and entrusted its erection to one of the most skilful "builders," M. Surcouf.

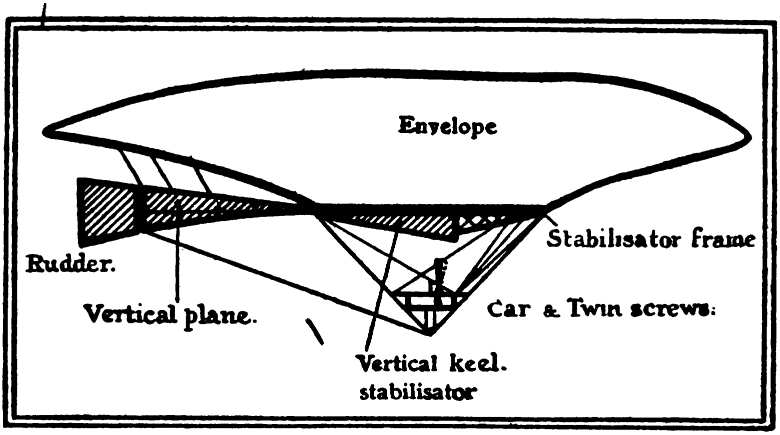


FIG. 33. The dirigible balloon *Lebaudy* (side elevation)

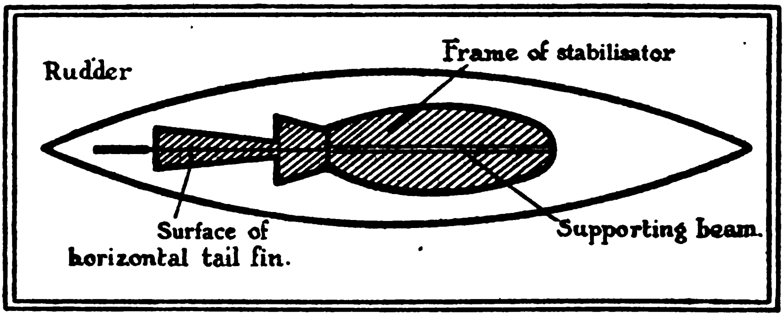


FIG. 34. The dirigible balloon *Lebaudy* (underside plan)

The *Lebaudy* balloon (Figs. 33 and 34), which the Parisians promptly christened the "Jaune" (yellow) owing to the colour produced by the coating upon the external surface of its envelope, measures 58 metres long by 9·80 metres master diameter: its elongation is consequently 5·6, while its total volume is 2300 cubic metres. It is dissymmetrical, the greatest diameter being forwards, and it is pointed at both ends. The body of the balloon is not completely "round," the lower part being truncated to form a flat plane surface resting upon a *frame* serving as the suspension medium for the envelope and the car. At the same time, the flat form of this framing acts as a "stabilisating plane," which is efficient in use. Under this frame is a "strengthened girder," which, covered with fabric, forms a vertical stabilisating plane extended into a veritable bird's tail, a stabilisator in itself, and which terminates in the rudder.

The car is short, and the motor which is carried therein transmits its power to two screws of 2·44 metres diameter, one being three, the other two, bladed. The propelling effort is exerted therefore not at the extreme front, as in *La France*, or at the rear as in the *Santos-Dumont*, but about amidships. The short length of this car renders difficult the uniform distribution of its weight upon the envelope: also the latter has a peculiar "saddle form;" it is hollowed towards its centre in the manner of a saddle, due to the weight of the car imposed upon the central part of the envelope. This arrangement has its disadvantage in this sense, that the general form of the balloon is altered, and in practice does not conform to the principles which have served in determining the theoretical conditions of equilibrium and of propulsion. It is just to add that the efficiency of this balloon is remarkable. The air-ballonnet is divided into three compartments, to prevent the heavier air surging towards the base in case the airship becomes tilted, and has a capacity of 500 cubic metres. The motor is of the Mercedes type, and develops 40 horse-power when running at 1200 revolutions per minute. An acetylene search-light of 100,000 candle-power, mounted with a projector, facilitates landing at night.

After a magnificent series of triumphant flights made in 1904, in the following year MM. Lebaudy offered this magnificent dirigible to the French Minister of War, who sent it to Toul. The State then decided to order a dirigible of the same "semi-rigid" type; this was *La Patrie*.

Save in some details, *La Patrie* was identical with the *Lebaudy*. Its volume was increased some 200 cubic metres by extending the length by 2 metres; the ballonnet was 650 cubic metres instead of 500, and the motor built by Panhard and Levassor developed 70 as against 40 horse-power. Lastly, instead of ending in a point the stern was rounded and fitted with a cruciform empennage for the purpose of securing still greater stability. An elevator of two projecting planes was fixed to the front of the horizontal stabilisating framework. Otherwise it was a sister airship to the *Lebaudy*.

The life of the *Patrie* was brilliant but short. After it had demonstrated its exceptional features such as no other airship had shown up to that time, after it had travelled under its own power from Paris to Verdun in seven hours without any incident on November 23, 1907, this magnificent dirigible some days later was caught in a gale which forced a descent. Despite the efforts of 200 soldiers the wind catching its enormous broadside surface tore the balloon from their hands, and bore it away in the storm. It passed over France and England, dropping pieces of its motor at different points on English territory, and disappeared into the North Sea, where it was perceived, still inflated, some days after the accident.

A new balloon of the same type, the *République*, was ordered by the French Government from MM. Lebaudy for national defence. The *République* presented some striking features: the impermeability of its envelope permitted it to remain inflated 110 days with one charge of gas. Its first flight, made in September 1908, lasted six and a half hours, and it covered over 200 kilometres in a closed circle. After the *Clément-Bayard* this was the most striking record of a complete trip without descent, and with return to the starting-point. The characteristics of the *République* were the same as those of *La Patrie* as well as the arrangement of the motor and empennage. The *République* had been "militarised," and had been commissioned for the defence of the eastern frontier of France, when an accident supervened, to which we refer in another chapter, cutting short the career of this magnificent airship. Owing to the sudden breakage of one of the propeller blades, the latter, impelled by the centrifugal force, crashed into the envelope, piercing it through and through, and precipitating the airship to the ground with its four officers, Captain Marchal, Lieutenant

Chauré, and Adjutants Réau and Vincenot who were killed by the awful fall.

Several new military balloons, on similar lines to the *République*, or the *Bayard-Clément*, are under construction—the *Liberté*, *Capitaine-Marchal*, *Lieutenant-Chauré*, and *General Meusnier*, among others, while large "aerial cruisers" of 6000 cubic metres capacity will be put into commission shortly.

BALLOONS WITH HOLLOW STABILISATORS: M. DEUTSCH'S "VILLE DE PARIS": M. CLÉMENT'S "BAYARD"

M. H. Deutsch de la Meurthe had not remained idle all this time. Not content with merely having encouraged aeronautics, he wished to become a militant himself: he therefore had an airship constructed after the designs of M. Tatin. This vessel, not giving the expected results, he ordered a second in 1906, and for this secured M. Surcouf, who had become instilled with the ideas of Colonel Renard. For the first time an empennage of inflated ballonnets, which we have already described in discussing longitudinal stability, was used. The body of the balloon (Fig. 35) is pisciform, with the master-diameter towards the front. The stern is connected to a cylinder carrying the stabilisating ballonnets. Its length is 60·50 metres; maximum diameter, 10·50 metres; volume, 3200 cubic metres. The car, lattice-work of metal tubing, is 30 metres long, and of the "trussed girder" form. The ballonnet, divided into three compartments, has a volume of 500 cubic metres, and two rudders are attached to the car, one for steering laterally, and the other for ascent and descent. The 70 horse-power motor drives a two-bladed propeller 6 metres in diameter, running at 900 revolutions. The screw, placed at the prow in conformity with the ideas of Colonel Renard, makes, through a reducing gear, 180 revolutions per minute. This huge airship has accomplished several successful flights, and it was on board this vessel that the Prince of Monaco, the eminent and scientific navigator, who has surveyed and sounded the ocean, received the "baptism of the air," the highest altitudes of which previously he had explored scientifically in mid-Atlantic by means of "sounding balloons."

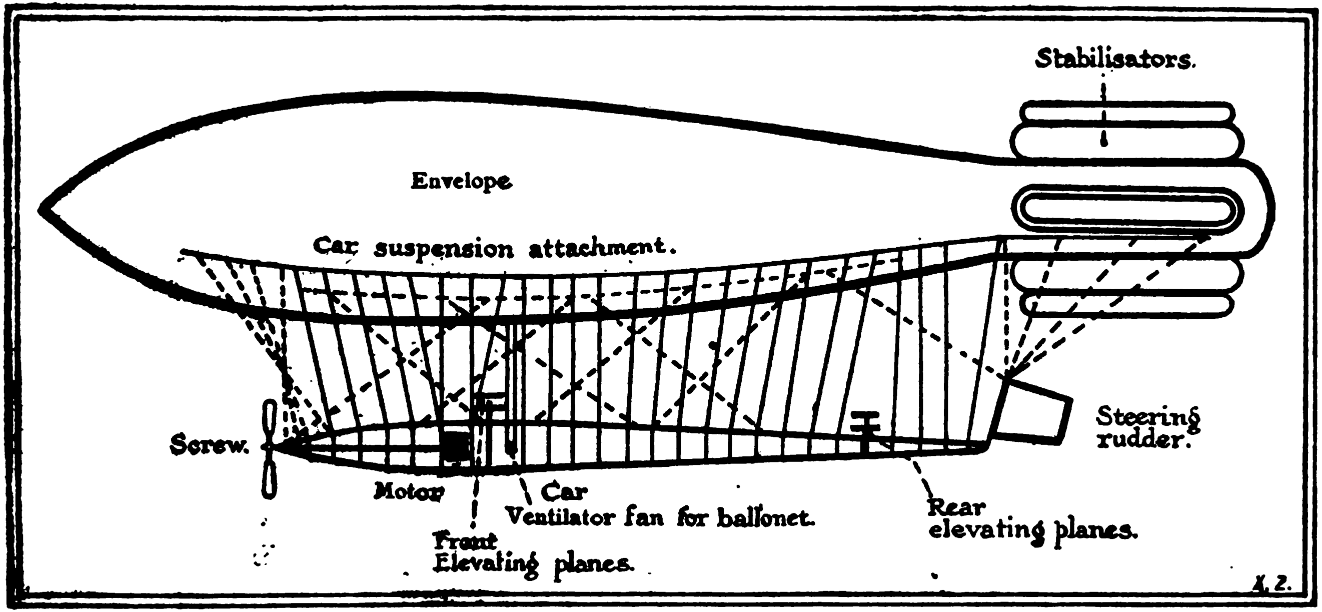


FIG. 35. The dirigible *Ville-de-Paris*, offered by M. Henry Deutsch to the French War Office

After the catastrophe which destroyed the *Patrie*, M. Henry Deutsch made a patriotic, generous offer; his balloon was ready; he submitted it to the French Minister of War to take the place of the lost airship, and the *Ville-de-Paris* set out from Paris to Verdun, under its own power, to replace the wrecked dirigible. This voyage was made on January 15, 1908 (Fig. 36).

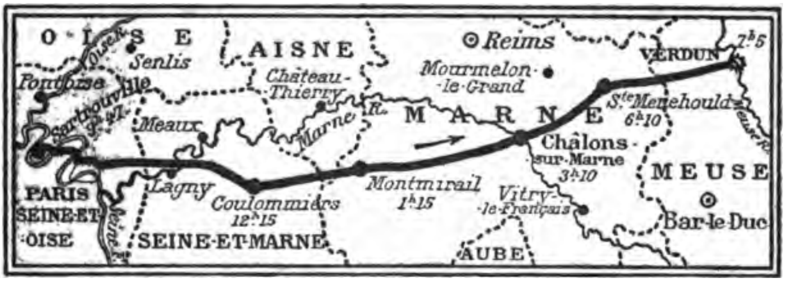


FIG. 36. Journey of the *Ville-de-Paris* from Sartrouville to Verdun (January 15, 1908).

During the exploits of M. Deutsch's balloon, M. Clément, one of the best-known automobile builders, ordered from M. Surcouf a dirigible of the same type, but a little larger—the *Clément-Bayard*. We have described it in detail already. A new airship, the *Ville-de-Bordeaux*, has recently issued from the Surcouf works, and its features appear to be in no way inferior to those of its contemporaries.

Finally must be mentioned the dirigibles of the *Zodiac* type, which have given such good results. To-day the *Zodiac* is made in three models—of 1200, 1400, and 2000 cubic metres capacity respectively.

FOREIGN DIRIGIBLES : COUNT ZEPPELIN'S AIRSHIPS

The attention of the Germans was drawn quickly to the gigantic progress in aeronautical travel effected in France. They at once foresaw its military applications, and anxious not to be left behind, resolved to excel the French constructors in the building of a gigantic airship—"colossal" as it is colloquially called in Germany. It was Count Zeppelin who, with a dogged perseverance, an ardent patriotism, which one cannot

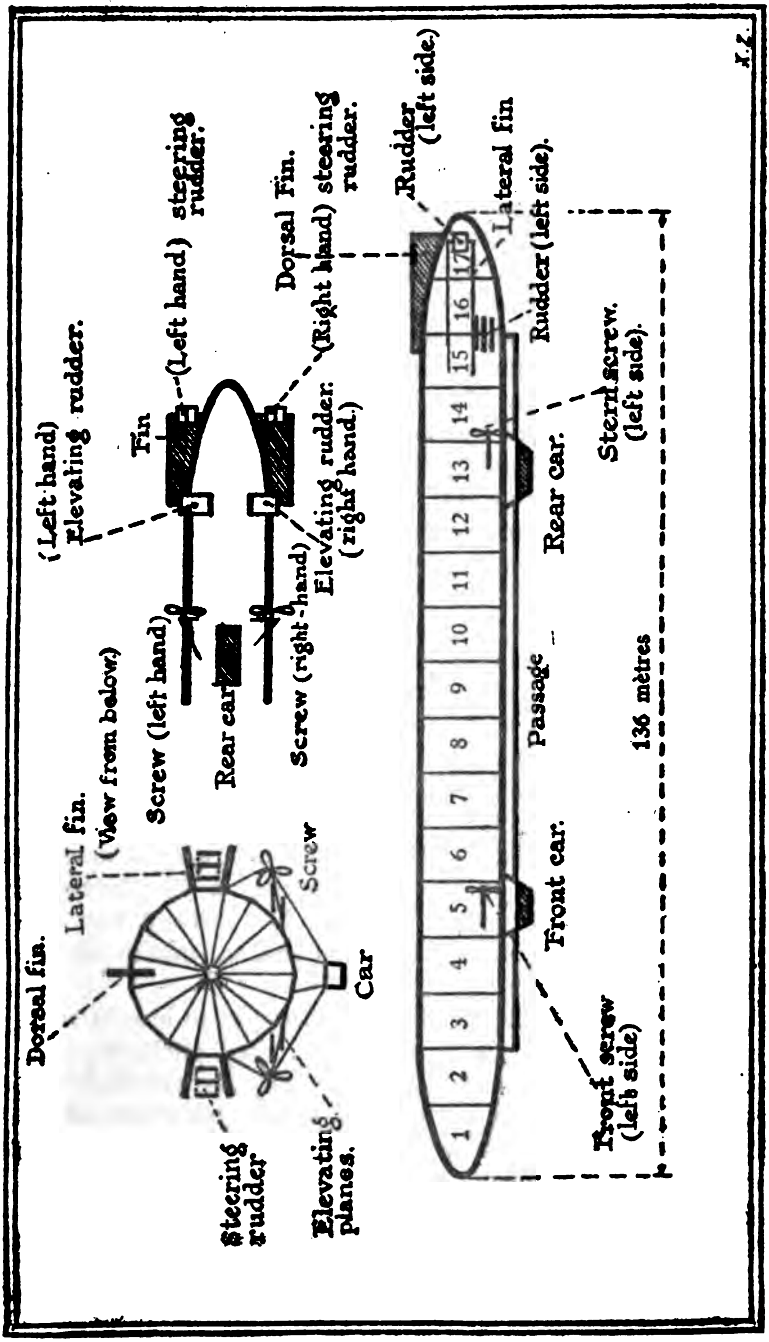


FIG. 27. The German dirigible *Zeppelin*

Compartment type of dirigible with rigid body but admire, concentrated his knowledge, his life, and his fortune, to the fulfilment of this idea. Moreover, his enterprise was sustained not only by H.I.M. Emperor William II. and by H.I.M. the King of Würtemberg, but also by national enthusiasm: he was advised by those admirable meteorological aeronauts who grace German science, and among whom figure Hergesell, Assmann, Berson, &c.

Conceiving an immense dirigible, Zeppelin sought to secure indeformability or rigidity by *construction*. He designed a gigantic airship 136 metres in length by 11·70 metres in diameter, and with a capacity of about 12,000 cubic metres. Its form was of a cylinder with pointed ends, the elongation being equal to 11 (Fig. 37).

Rigidity was secured by means of a metallic framework, in aluminium, which not only gave to the system the rigidity much sought after by its inventor, but enabled him to divide the huge cigar into numerous compartments: 17 in all. Each of these was 8 metres long, except those 5 and 13, which corresponded to the two cars, and which were not more than 4 metres in length. The rigidity of the skeleton was secured by transverse partitions formed of cross-bracing covered with fabric. It will be seen that this balloon was not provided with a ballonnet.

Each compartment contained a balloon of india-rubber fabric partially inflated (nine-tenths only); the inflation of these 17 balloons was a lengthy and difficult operation.

The whole of the skeleton was covered with stretched fabric. The two cars were attached to the balloon in a rigid manner, and connected by a bridge, along which a counterweight travelled. The two motors were of 170 horse-power, and drove four propellers of 1·30 metres diameter, running at 800 revolutions per minute.

Such a mass is difficult, if not impossible, to handle upon the ground; so its home was a floating shed, anchored upon Lake Constance. This "dock," held only at one end by a powerful hawser, swings itself round under the action of the wind, so that the entrance is always to "leeward" for the emergence of the balloon.

Such is—or rather such *was*—the first aeronautical monster. The German military authorities, as a condition of its definite acceptance, demanded the accomplishment of a *trial trip* of twenty-four hours "without descent or replenishment of fuel tanks, &c." It was during the summer of 1908 that this balloon, the fourth built by its learned author, attempted this official journey. After several short flights, carrying successively the King of Würtemberg, the Queen, and some royal princes, the *Zeppelin* set out on August 4, 1908, from its shed at Friederichshafen. There were twelve passengers on board. At 6.45 in the morning it rose above the lake and set a course to the west; it passed over Basle, where it veered round to the north; over Mulhouse and Strasburg, where the clanging of church bells and the salvoes of artillery greeted its passage; at 2.45 P.M. it was over Mannheim, when, before reaching Mayence, there was a slight "mishap." The fault repaired, the balloon resumed its journey, passing over Mayence during the night, and the return journey was commenced. At 6.30 A.M. it was approaching Stuttgart, but when some miles south of this town another mishap necessitated descent. Here a squall struck the balloon, and from a cause still but little explained the immense airship was completely destroyed by fire in a few moments! This was a national loss to Germany, and in a magnificent outbreak of patriotism a public subscription raised in a few days the millions of marks necessary to replace the aerial vessel. Such is an example to be followed. During the erection of a new airship Count Zeppelin re-commissioned *Zeppelin No. III.*

Yet *Zeppelin No. IV.* accomplished a magnificent performance: its voyage of August 4 and 5, 1908, covered, as a matter of fact, 606 kilometres, with two descents, and represented an actually travelling sojourn in the air of twenty hours forty-five minutes. With the new *Zeppelin* the record for duration and distance was excelled on May 31, 1909—1100 kilometres in *thirty-eight hours!* Unfortunately the difficulty of handling such a mass as this again proved disastrous, for the airship came to grief against a tree. Despite its injury it was able to return to its shed after completing this noteworthy journey.

This second accident was followed by the destruction of a third *Zeppelin.* On June 29, 1910, the monster of this series of rigid balloons, the *Deutschland*, of 19,000 cubic metres, 148 metres long, and driven by three motors developing in the aggregate 330 horse-power, giving a speed of 55 kilometres per hour, was launched. But this, like its prototypes, met with disaster. It became stranded in a forest and was totally destroyed. In the month of September 1910 a fifth balloon of this type came to grief. Such practically demonstrates the fallibility of the rigid system.

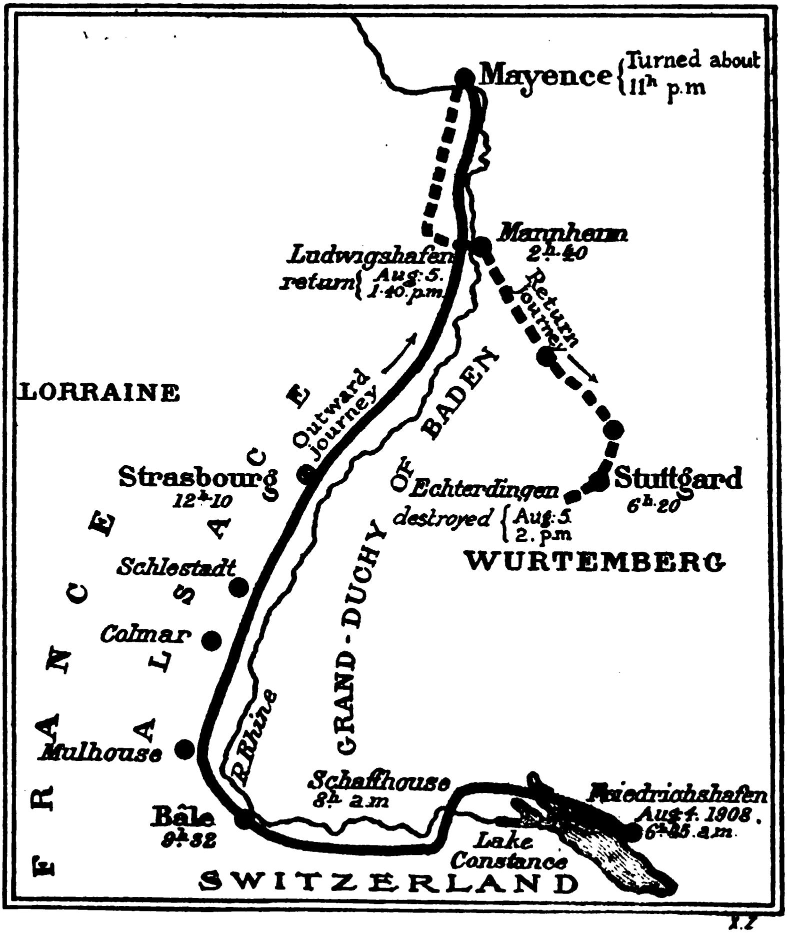


FIG. 38. Voyage of the *Zeppelin*, August 4 and 5, 1908

606 kilometres were covered when the airship was destroyed

The future of the dirigible is undoubtedly in the "supple" airship.

PROGRESS OF MILITARY AERONAUTICS IN GERMANY: THE THREE *ZEPPELINS*, THE *PARSEVAL*, THE *GROSS* AIRSHIPS : THE GRAND MANŒUVRES AT COLOGNE

But German military aeronauts were not dismayed. Through the enthusiasm of the nation, the patriotism of its representatives, the initiative and enterprise of Emperor William II., a whole aerial military fleet was constructed, not entirely after the *Zeppelin* lines, but also with the supple or semi-rigid types, evolved and built by two famous German officers, Majors von Gross and von Parseval, after whom the respective airships are named. The *Gross* airship follows closely the designs of the *Patrie* or the *République*, the empennages and the tapering of the stern of which have been adopted. This is a remarkable vessel, and has made a *trial trip* of thirteen hours without descent.

With regard to the *Parseval*, it is one of the most perfect expressions of modern aeronautics, not only on account of its design, but owing to its striking efficiency. The *Parseval* is a beautiful and well-thought-out piece of work; everything is the outcome of experience. The car has a suspension combining the advantages of the parallel and the triangular systems. Two ballonnets, placed respectively fore and aft, one of which deflates while the other inflates, have their envelopes guided by internal pulleys as shown in Fig. 40. Not only do they serve to secure the permanency of shape, but the difference in weight brings into play one or the other to assist the elevating rudder to secure the inclination of the balloon in any direction. Lastly, the propeller is quite an interesting piece of work. When stationary its blades, composed of fabric stretched tightly over a flexible framework, fall limply lengthwise upon the frame supporting the propeller. But when the latter is set revolving the blades open out. Under the combined action of centrifugal force and the resistance of the air, the wings assume the best disposition from the point of efficiency. Undoubtedly the *Parseval* is a marvel of modern aeronautical construction.

The German army has at its command *thirteen* dirigibles. Three are *Zeppelins* of 15,000 cubic metres each, while there are several *Gross* and *Parseval* vessels respectively. And if the *Zeppelins* are not of practical use, on the other hand the *Gross* and the *Parseval* are military engines of the front rank. Not only are these balloons kept ready for instant action, but, moreover, there are large sheds which can harbour several

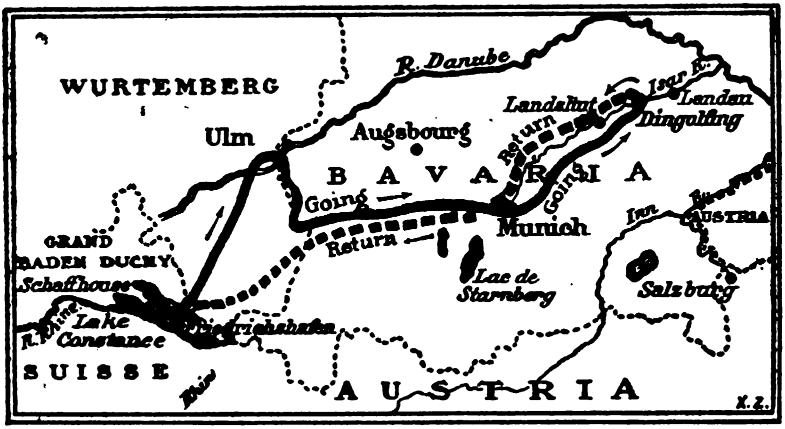


FIG. 39. Voyage of *Zeppelin III.* in a complete circuit (April 1909)

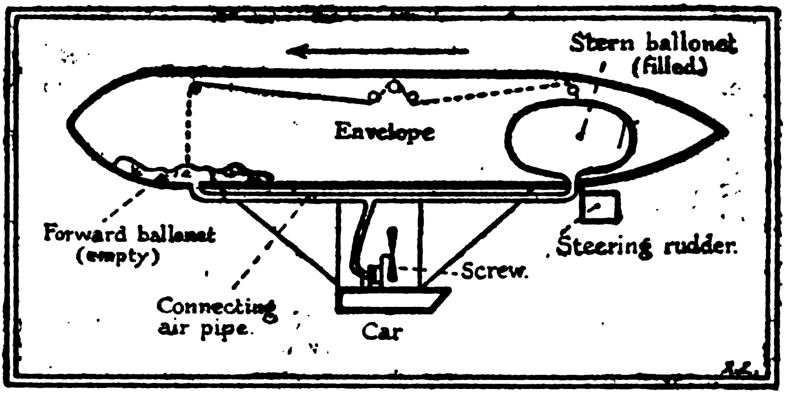


FIG. 40. The German dirigible *Parseval*

The suspension system is both parallel and triangular, and the two ballonnets, operating independently, are able to meet any ascensional inclination movements of the balloon machines at the same time. At Cologne, where the grand manœuvres, especially for dirigibles, were held in October 1909, one shed in particular held simultaneously a *Zeppelin*, two *Gross*, and two *Parseval* vessels. Similar sheds have been provided at Metz, Aix-la-Chapelle, and at other points on German territory.

But that is not all: stores, large depots, have been established where are held in reserve from 15,000 to 20,000 steel cylinders charged with *pure* hydrogen under high compression. These cylinders are carried in special railway cars, so that upon receipt of a command for "service" they can be attached to the first express train travelling in the direction of the point where the hydrogen is required. With a train of this description it is possible to inflate a *Zeppelin* in a very short time.

Finally a corps of more than *two hundred aeronautical officers* has been formed. The latter have been drawn from various branches of the service; even from the navy. Carefully selected, highly trained, they constitute an aerial staff of first-class efficiency.

In addition to these military airships, always ready for service, there is the German aerial fleet which can be mustered from among private owners. It is possible to rely upon *fifteen* excellent dirigibles in case of war. This secures a combined effective aerial fleet of twenty-eight vessels available to German military aeronautics in case of hostilities.

Germany, despite its unique position, is not to be lulled into a false sense of security. In addition to the *Zeppelin*, the *Gross*, and *Parseval*, there is a fourth type. This is the *Ruthemberg* airship. Well designed by its authors, it is characterised by the use of a long "trussed girder" carried directly under the envelope, and which supports the car or cars, according to the dimensions of the vessel.

Thus it is possible to realise the magnificent effort which Germany has made in the direction of dirigibles. If France had the honour of "discovery," Germany had the foresight to "profit." Germany certainly occupies first position in respect of airships. For France to be overtaken by its neighbours after the former had shown the way in 1884–1885, is a curious situation indeed. Happily France has the aeroplane. In this latter phase no country has yet surpassed or even equalled our neighbours across the Channel. The French aviating officers astonished the world at the Picardy manœuvres, and the French by means of their aeroplanes and their aviators are the unrivalled "masters of the atmosphere."

ENGLISH, ITALIAN, AND BELGIAN DIRIGIBLES

In England military aerostation has been represented by the construction of the airship *Nulli Secundus*. The career of this dirigible was short, but no doubt we are following progress in the new science minutely so as to effect something striking in a single move. It led to the construction of the *Morning Post* vessel for the nation at the Lebaudy shops, which was driven over to London by M. Capazza.

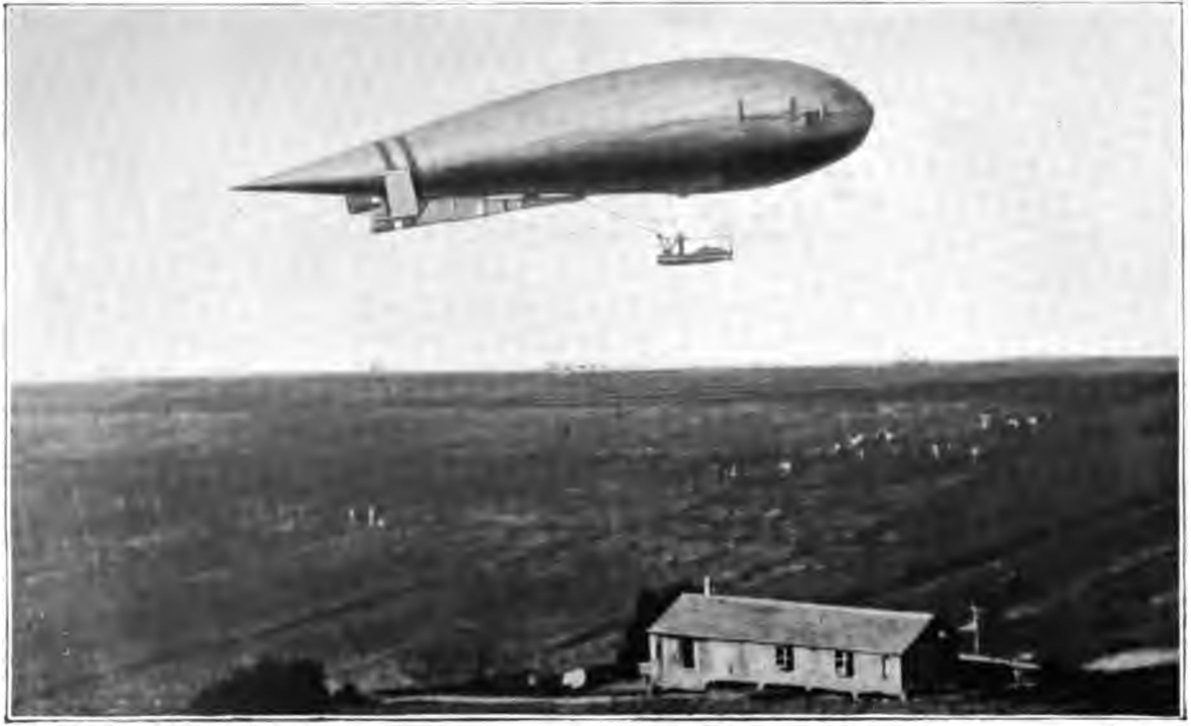
In Italy the military aeronautical service has evolved an airship which is in every way remarkable, and which, as we shall see in a moment, has one of the highest *coefficients of advantage* among dirigibles actually existing.

This balloon, known as *1-bis*, is pisciform. Its total volume is 3500 cubic metres. The envelope is divided into seven compartments. The volume of the ballonnet is 650 cubic metres; and it has a length of 60 metres, by 10·50 metres maximum diameter. The car is 8 metres long, and follows the lines of a motor-boat, which the aerial screw is able to drive like a "hydroplane" should it settle on the water. The 86-horse-power *Clément-Bayard* motor drives two screws of 3·40 metres diameter, running from 600 to 1200 revolutions per minute, which give the airship a maximum speed of *53 kilometres per hour*, one of the highest speeds attained up to this time in dirigible construction.

The total weight of the balloon is 2500 kilogrammes. With a capacity of 3500 cubic metres it can lift 1100 kilogrammes, made up as follows: 4 aeronauts, weighing 75 kilogrammes each, representing 300 kilogrammes; fuel, 300 kilogrammes; ballast, 300 kilogrammes; accessories, 200 kilogrammes.

The salient feature of this vessel, a feature which renders it an absolutely new type, differing entirely from the German craft, is the happy combination of the "rigid" and the

PLATE XIX



THE FIRST ITALIAN MILITARY DIRIGIBLE MANŒUVRING OVER BRACCIANO *Photo, Rol*

PLATE XX

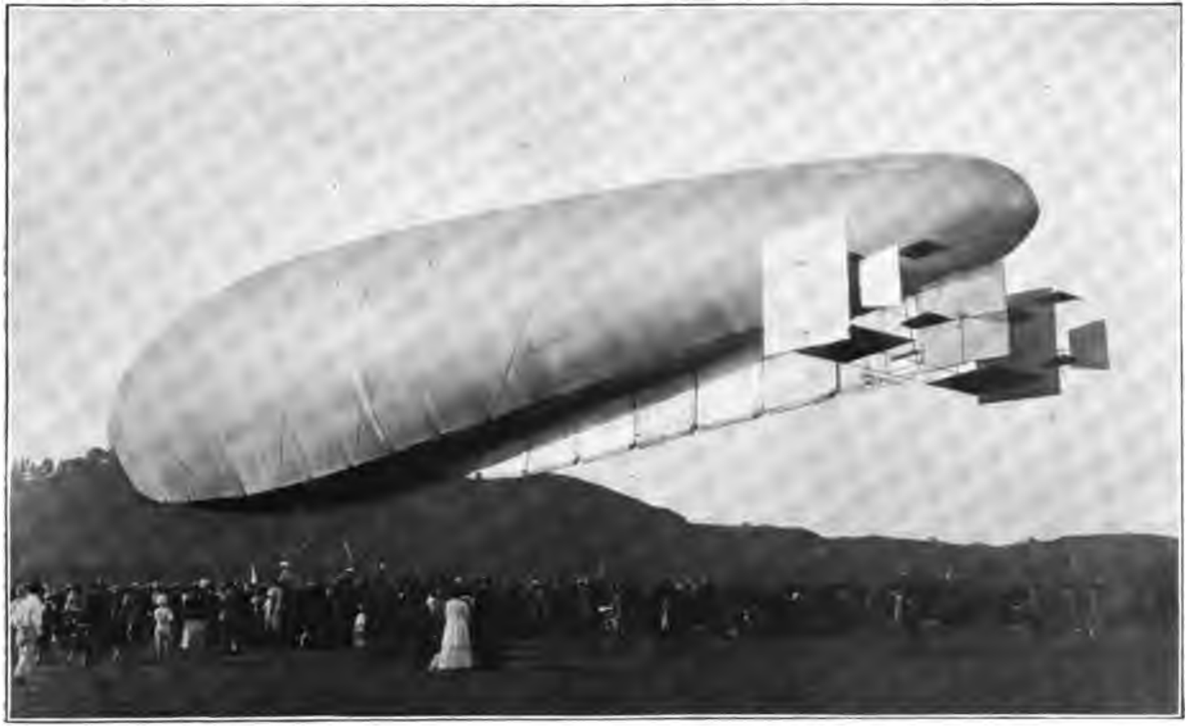


Photo by permission of Engineer G. L. Pesce

THE NEW ITALIAN DIRIGIBLE "I-BIS"

"flexible" systems. There is a metallic framework, but instead of forming an immense and indeformable cylinder, as in the case of the *Zeppelin*, this skeleton is articulated. It is built up, if I may risk a comparison which seems to me to be most apt, of a series of "vertebræ," comprising huge hoops of steel over which the envelope is stretched.

The floor consequently is rigid in the transverse, and flexible in the longitudinal direction, in such a manner that it can follow lengthwise all the movements of the envelope, movements so variable especially during inflation. A detachable "keel" formed of a tubular steel framework extends under the rear half of the bottom, and in contact with the balloon. This ensures an excellent longitudinal stability.

With regard to the steering mechanism—the elevating and lateral steering rudders—this is attached to the stern of the envelope itself, beneath the empennage.

This vessel was designed and built under the expert and masterly direction of Lieutenant-Colonel Moris of the *Brigata specialisti*, ably assisted by the two valuable officers, Captains Ricaldoni and Crocco.

A Belgian sportsman, M. Goldschmitt, has built an airship bearing the name *Belgium*. It carries two independent motors of 50 horse-power each, two independent propellers, and is of 2700 cubic metres capacity. Its length is 54·80 metres; master diameter 9·75 metres. It can carry four persons, remain ten hours in the air, and travel at 40 kilometres per hour. Consequently its radius of action is 200 kilometres. Stability is secured by a cruciform empennage. This vessel was built at the workshops of M. Godard.

Moreover, an aeronautical construction society has been established in Belgium. Strongly supported financially, it has placed on the stocks a powerful airship, *La Flandre*, of 6000 cubic metres. During the Exhibition of 1910 the *Ville-de-Bruxelles* made several successful ascents. Lastly, let us remember the brilliant excursions of the Swiss dirigible *Ville-de-Lucerne*, constructed at the *Astra* workshops.

COMPARISON OF DIFFERENT TYPES OF DIRIGIBLES : THE "CO-EFFICIENT"

We see many types of dirigible balloons, widely different from one another. Each corresponds, in short, to a new idea; each, one may say, indicates a development. But what is the net result? In short, which is the best airship?

The problem is complex, more so even than in the case of steamships where there is something upon which to go. Accordingly, I have attempted to resolve it, and I hope, even if it is not complete, at least to have introduced a new factor in aeronautics—the "*co-efficient of advantage*" of dirigible balloons.

To evolve a mathematical formula combining speed with the shape of the aerial vessel, motive power, and dimensions of the propeller, is still somewhat impossible, there being many factors to take into consideration to formulate such a calculation. But, inspired by the example of Dupuy de Lôme in connection with steamships, I have sought to find an "empirical" formula. On the basis of results of experiments spread over a period of fifty years, the clever engineer evolved a formula called the "French marine formula," which has the advantage of simplicity.

By a slight modification I have applied it to aerial navigation. This is how it is worked out; it is a simple arithmetical problem by no means difficult, only requiring a little thought, and as much within the comprehension of the pupil of the ordinary school as of the university or college student. The power of the machine, expressed in horse-power, is taken, and divided by the number of square metres contained in the maximum section of the envelope. This gives a quotient, of which the cube root is then found. Then it is only requisite to divide the independent speed of the airship, expressed in myriametres per hour, by this cube root: the result of the division is a number, *always between* 3 *and* 5, which qualifies the airship—this is *its co-efficient of advantage.* This number expresses the *value* of the airship in exactly the same manner as the *mark* given by the examiner, to a young man who passes an examination, expresses the position of the candidate in relation to his

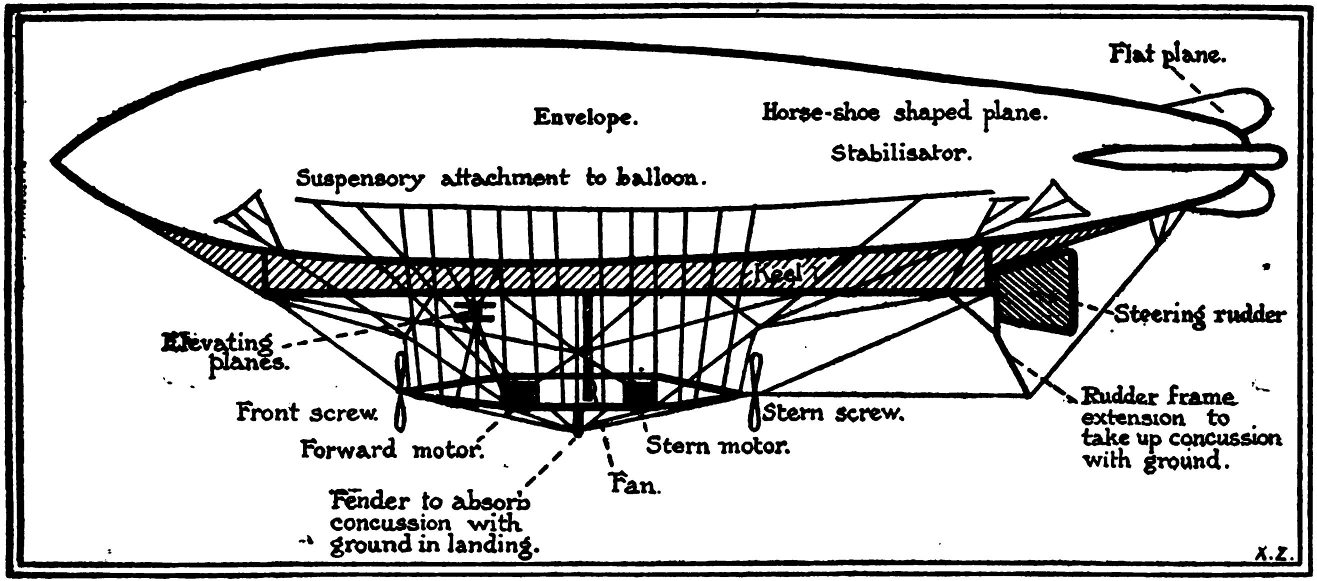


FIG. 41. The dirigible *Belgium*, fitted with two motors and two propellers

competitors. The value of this number takes into consideration all characteristics which theory is still powerless to calculate correctly—lines of longitudinal sections, resistance of the air, efficiency of motor; as well as pitch, slip, and efficiency of propeller, &c.

In working with a number of dirigibles of which I have been able to obtain definite data, I have in every case been able to obtain an individual co-efficient, which will be found in the following Table:

TABLE SHOWING CO-EFFICIENT OF ADVANTAGE IN REGARD TO DIRIGIBLE BALLOONS

Names of Dirigibles.[1]	Section.	Proportion of length to diameter.	Horse-power.	Speed.	Value of coefficient C.	
Giffard (F.)	113	3·66	3	0·90	3·20	
Dupuy-de-Lôme (F.)	173	2·45	3	0·80	3·08	
Tissandier (F.)	66	3·00	1·5	1·08	3·80	
La France (Renard et Krebs) (P.)	55·4	6·00	9	2·33	4·24	
Santos-Dumont (F.)	27·9	5·50	16	2·70	3·26	
Lebaudy (P.)	84	5·60	40	3·25	4·20	
Patrie (P.)	93	5·50	60	4·00	4·60	
Clément-Bayard (P.)	90	5·00	100	4·50	4·31	.0416
République (P.)	93	5·50	60	4·00	4.60	0.151
Zeppelin (Cyl.)	106	11·00	170	4·00	3·47	
Parseval II. (P.)	68	5·00	100	4·20	4·04	
Militaire Italien (P.)	90	5·00	70	4·50	4·90	
„ „ *1-bis* (P.)	86	5·7	100	5·30	5	.0214

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[1] (F.): fusiform; (P.): pisciform; (Cyl.): cylindrical.

Therefore, by means of this co-efficient, one has a means of "classifying" the balloons in their order of merit absolutely the same as in an examination. The mark attributed to each candidate permits its classification in relation to its colleagues. The more the co-efficient is in the neighbourhood of 5, the more advantageous is the airship, whereas its efficiency is indifferent if the co-efficient drops below 4.

This simple method shows the superiority of Colonel

Take $\frac{V^{\frac{2}{3}} v^3}{p}$ = coef.

V = vol

v = speed

Renard's ideas. The form of all dirigibles which does not follow that of the fish (the latter he maintained to be indispensable) have an inferior co-efficient. The *Zeppelin*, notwithstanding its huge elongation, reaps but slight advantage from its motor. On the other hand, *La France*, built twenty-five years ago, had an excellent co-efficient. The best are the *Patrie*, the *République*, and the *Italian* dirigible. In particular, the co-efficient ~~4 to 6~~ of French military balloons of the 4.6 *République* type is remarkable, inasmuch as these balloons only have 60 horse-power motors, and always carry a heavy bulk of disposable ballast—from 700 to 800 kilogrammes.

If it is pointed out that the co-efficients inferior to 4 affect all fusiform or cylindrical balloons, one may go further and say that *in all pisciform balloons having the greatest diameter at the prow, the coefficient of advantage will always be between* 4 *and* 5.

WHAT ARE THE IMPROVEMENTS TO BE EFFECTED IN AIRSHIPS?

An independent speed of 45 kilometres per hour, therefore, may be considered fulfilled by airships commercially constructed to-day. This speed enables them to set out in the vicinity of Paris with the certainty of being able to cope with the wind, and to steer in all directions for, on an average, about 300 days during the year. Such is a remarkable achievement without a doubt, but it is not sufficient.

A speed of 70 kilometres per hour—that is, 20 metres per second—must be attained to enable them to go out on an average for 350 days out of the 365; thus the impossible days would number only fifteen per annum, and these would be wildly tempestuous days. Will it be possible to attain these speeds, and to increase the velocity from 13 or 14 to 20 metres per second? Such will be reached probably, but it will be difficult, since it will be necessary to employ more powerful motors. Calculations show that if 13 metres per second are obtained upon a certain airship with 100 horse-power, it will be necessary to use about 450 horse-power to give the same vessel a velocity of 20 metres per second; undoubtedly the motive power must be divided between two engines and two propellers. Thus a much more powerful—that is to say, heavier—motor would have to be used, consuming four times as much fuel, and the aerial vessel's radius of action would be decreased. The balloon itself would have to be provided with a stronger and heavier envelope, to be able better to resist the greater thrusts that the increased speed would bring to bear upon its surface. Perhaps it would be necessary even to resort to compartments, which would increase the weight still more.

The solution of high speed demands, consequently, that airships shall be far larger and carry far more powerful engines. But then another point arises—that of the resistance of the air, which is proportional to the square of the speed. Again, the balloon will assume an inclination, and will lift its nose slightly the action of the air will tend to lift the envelope as it lifts a kite. One consequently reflects whether, in the case of an airship of large dimensions, the naturally rising balloon, travelling at a certain speed, would not be able to sustain itself in the atmosphere without aerostatic intervention by virtue of the Archimedean thrust, and solely by the effect of the velocity of the air upon its suitably inclined surface. In other words, whether it would not be possible, under these conditions, to dispense with the "aerial float."

Colonel Renard calculated that, with an airship of the dimensions of *La France*, this result would be obtained when the speed attained 72 kilometres per hour. In that case there would be no more need for the encumbering, expensive, and dangerous hydrogen, and we could rise into the air under a purely mechanical effort by an apparatus *heavier than the air*.

This brings us to the study of this second form of aerial navigation which has opened up so brilliantly in the form of the *aeroplane*.

PART II

AVIATION APPARATUS

CHAPTER I

THE PRINCIPLES OF AVIATION

THE "HEAVIER THAN AIR" PROBLEM : BIRDS AND KITES : THE PROBLEM OF EQUILIBRIUM : HOW IT CAN BE OBTAINED : DIFFERENT FORMS OF AVIATION : THE AEROPLANE

WHAT IS AVIATION?

AVIATION is the art of lifting and propelling through the atmosphere a body "heavier than air," by utilising the resistance offered by the gaseous element to the movement thereof.

If the first successes of man in aerial navigation were due to the invention and use of aerostats, undoubtedly his first ambition was to emulate the birds, which are "heavier than air." Centuries of thought were required to grasp the physical principles upon which the action of the aerostat is based. On the other hand Nature had placed before our eyes marvellous travellers through the air—the birds. As a result it may be affirmed that it was aviation, which, from the first, haunted the minds of those ambitious to traverse the atmosphere.

But now the solution has been found. Although man has not realised yet in a satisfactory manner the solution as presented by the bird, yet the problem has been resolved by three quite distinct types of flying apparatus. These are:

The *Ornithopter* (sometimes called orthopter), which is an apparatus having "flapping wings," imitating the bird's method of propulsion and sustentation.

The *Helicopter*, an apparatus which uses simply the action of screws, as much for sustaining as for moving and steering.

Aeroplanes, utilising, by means of large oblique surfaces, the resistance of the air for sustentation under a horizontal speed imparted by the screw-propeller.

Ornithopters have been tested but rarely. Helicopters, very fascinating at first, have been relegated now to a second position. Only aeroplanes (the study of which has been pursued really rationally only during the past two years) have developed with such rapidity, and furnished such convincing proofs of their practical value, as to enable it to be conceded that the problem of aviation is solved at last. Consequently we shall devote the following pages almost exclusively to their study.

HOW BIRDS FLY

Before discussing aviation, such as is practised to-day by man, it is necessary to examine flight as fulfilled by birds, those inimitable natural aviators, the Latin name of which (*avis*, bird) has furthermore provided the appellation for the new trans-atmospherical locomotion.

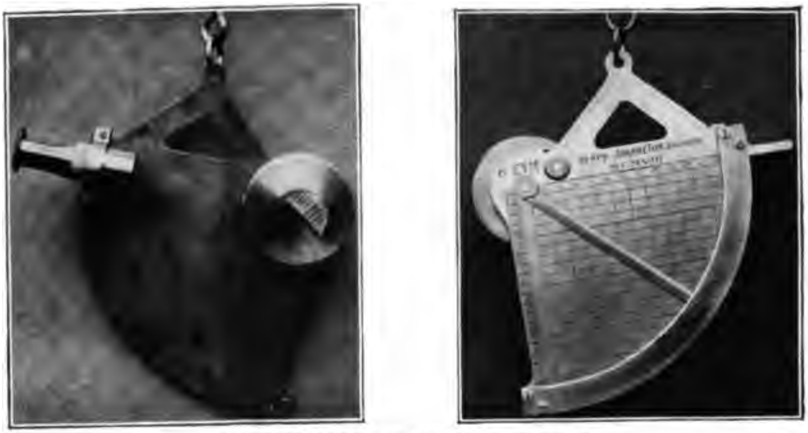
Being heavier than air, birds sustain themselves therein by utilising the resistance of this element to their movement. This resistance, as we have seen when speaking of "dirigibles," is proportionate to the moving surface, and increases as the square of the speed. Birds oppose to the air very large "sustaining" surfaces, known as wings. Also they have an organ, the tail, for balancing and guiding at the same time. The complex movement of their wings, securing a fulcrum by striking the air, enables them to force their way forward.

Bird flight appeared mysterious for a long time, but, as Marey's works distinctly proved, it is effected in three distinct ways.

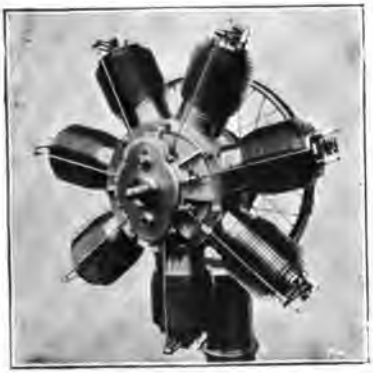
There is, first of all, the "*flapping*" flight, where the birds beat their wings to keep themselves up and to move about as desired.

Then, there is the *soaring* flight, practised by the bird when, hurled on at a great speed, it ceases to beat its wings, but keeps them outspread. Owing to the large surface of the latter, gliding on the resisting molecules of the air, the bird only has to steer

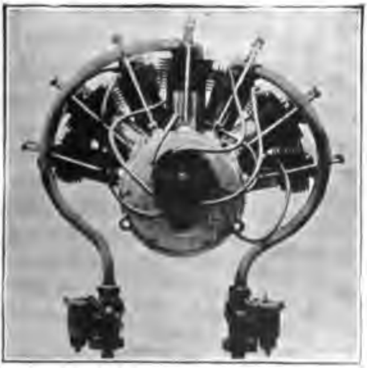
PLATE XXI

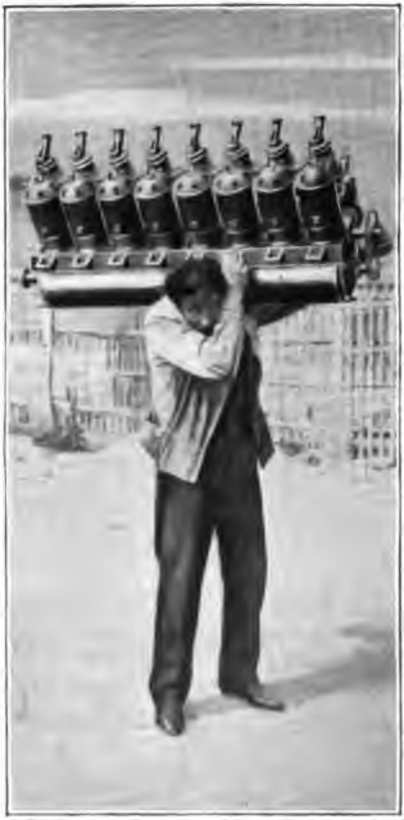


THE JOANNETON AIRSHIP SPEED RECORDER



THE GNOME LIGHT MOTOR





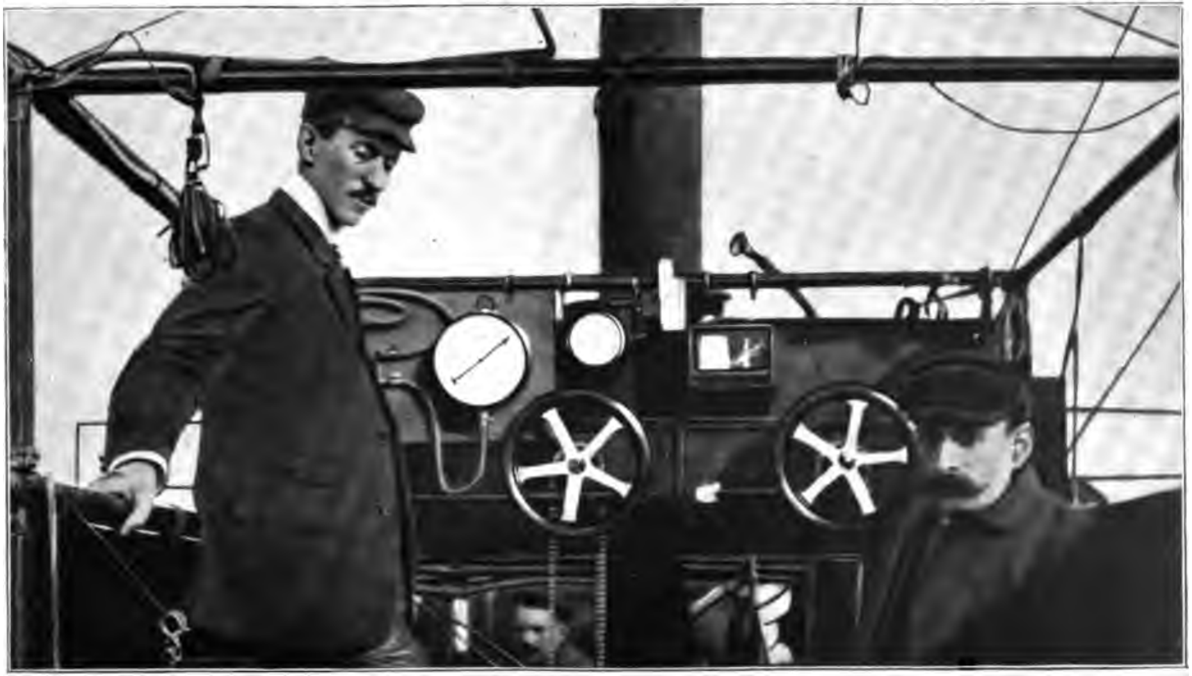
Photos, Rol

THE ESNAULT-PELTERIE LIGHT MOTOR

Photo, Branger

A 100 H.P. ANTOINETTE AVIATION MOTOR

PLATE XXII



M. Kapférer M. Sabathier *Photo, Branger*

BRIDGE SHOWING STEERING AND CONTROL MECHANISM OF "BAYARD-CLÉMENT NO. 1"

Steering wheel at left, stabilisator wheel at right while moving forward. It is this phase of the bird's flight which the aeroplane imitates.

Lastly, certain large birds, such as the albatross and the frigate-bird, practise the *sail* flight, in which, without muscular effort, they press into service the varying wind velocities—the "gusts" which occur in the atmosphere. When the bird feels the speed of the wind to be increasing, it faces the latter, and with wings outspread allows the wind to bear it along, both in ascension and progression. When it feels that the gust has reached its maximum speed, and is about to decrease, it turns round and glides, owing to the velocity and altitude it has acquired with the wind behind. During this gliding action it can attain and maintain high velocities, therein bringing into practice the gliding plane. At the moment it feels the advance of another squall, it turns round once more, head to the wind, and the same cycle of operations is repeated. In this manner it utilises the variations in wind velocity without any muscular efforts beyond those necessary for reversing from time to time. With marvellous animal instinct, it will be able to profit advantageously from the fluctuating intensity in the successive gusts, and will manage even to "gain upon the wind."

How are these gusts produced? So long as one is near the surface of the ground, it may be admitted that they originate from the varying reflections of the horizontal wind by the projections promiscuously scattered about the terrestrial surface, without any regard to geometrical laws. But it has been proved often that such gusts exist at great atmospheric altitudes. What, then, is the cause? Are they due to fluctuations in the intensity of solar radiance, according as to whether more or less opaque clouds interrupt the passage of the sun's rays, and thus produce unequal heating of the atmospherical masses?

Until careful observations, vital to aerial navigation, are made, concerning these phenomena, by aerostatic means, one must be satisfied with the conception of the dynamical state of the atmosphere as set forth by a clever French engineer, M. R. Soreau, an old pupil of the École Polytechnique, President of the Aviation Committee of the Aero Club of France, and one of the savants whose excellent theoretical studies have contributed perhaps most to the "unravelling" of so complex a question as aviation.

M. Soreau compares the state of the centre of the atmosphere with that of the surface of the ocean. Every one knows that the open sea is traversed always by "wave" systems obeying well-determined rhythmical laws, of which the "swell" is the most common and simplest manifestation. According to this clever engineer, the atmosphere is the seat of similar aerial waves, communicating to the gaseous masses vibratory movements of a perfect regularity. The progress of the latter is uniform because at an altitude they are too distant from the ground and its projections for their regular line of movement to be susceptible to confusion. It is from such "atmospherical waves" that the bird profits in most cases of sailing flight.

Will this sailing flight ever be accessible to man? In view of the more and more powerful, and at the same time lighter and lighter, motors, which he constructs, will man ever be in a position to achieve this end? For my part, I do not think so. But it is interesting to bear in mind this variety of flight, which we see practised by birds having a large wing surface, the "great sailers" as they are called, which cleave the air above the ocean, and the fury of which is let loose by the tempest. Even then, these birds will utilise those "ascending currents of air," caused by the reflection of the prevalent wind upon the oblique slopes of the immense waves of the Atlantic and of the Southern seas, where the height of these liquid hills reaches 16 to 18 metres. This explains why, by resorting to this gliding flight, these "birds of the tempest" always keep quite close to the disturbed surface of the ocean.

As to the "wheeling" flight practised by birds of prey, in reality this is gliding. Sometimes when these birds are seen rising, gaining height whilst describing their majestic circles—as, does, for instance, the buzzard—it is because in so doing they utilise an ascending current of air, which is often produced in summer above abnormally heated ground.

Hence, when soaring, the bird moves without effort. But a deep study of its movements shows that its wings fulfil two distinct functions—propelling and sustaining surfaces respectively. Moreover, it is the extremities of the wings especially which propel the animal, the central area serving principally for sustentation.

Why has man not sought the solution of the problem of aviation merely in the imitation of the bird flight? It is because human thought has conceived, and has realised, a more general and more efficacious mechanical movement than those which exist in Nature—*rotary motion*, of which Nature does not offer us any example, except in regard to celestial bodies. But there is a powerful reason for this peculiarity. Owing to all living beings being liable to growth as time progresses, their propelling organs must enlarge freely, in proportion to this growth. Such would not be possible always in combination with rotary organs.

Man has sought, therefore—and success has shown that he has done so with reason—to accomplish high travelling speeds on land and sea by means of revolving apparatus—wheels, screws, turbines, &c. He has been able thus to attain and to exceed the speed of the fleetest of animals. Now, why should what is good on land and sea not suffice for the air? We do not construct motor-cars with feet nor transatlantic boats with fins. Therefore we may seek for propulsion through the atmosphere otherwise than by flapping of wings. If we use *wings* for sustentation we must at least concern ourselves with machines and revolving propellers to move in the Aerial Ocean.

THE FORERUNNER OF THE AEROPLANE: THE "KITE"

The excessive weight of the "human motor," a weight which, as we have seen (page 7), approximates 1000 kilogrammes per horse-power, appears to forbid man the realisation of flight, by the use of his own muscular effort. All who have tried to solve the problem of aviation in this manner have failed.

But from time immemorial a means of raising bodies "heavier than air" into the atmosphere has existed. This is the "kite," that toy, which has now become one of the most valuable instruments in scientific investigation, but which has been known in China and Japan from the most remote days.

It is scarcely necessary to define the kite, which we have all handled, more or less. It is a rigid frame of wood and strings, on which is stretched a surface of fabric or paper. A string holds the apparatus to the ground, and when the wind reaches a sufficient velocity the contrivance lifts itself into the air. If the surface of the kite is sufficiently large, it may even lift objects—meteorological instruments or photographic apparatus.

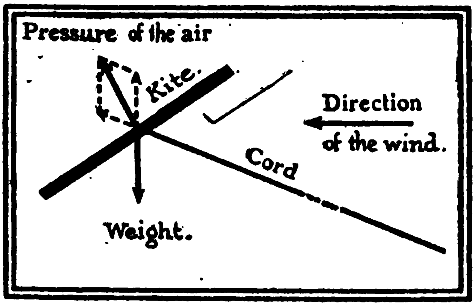


FIG. 42. Equilibrium of the kite

The kite is kept in equilibrium under the combined action of its weight, pressure of the wind, and resistance of the string by which it is held

The equilibrium of the kite is due to the combination of the forces which bear upon it (Fig. 42). The surface exposed to the wind is, in fact, kept "oblique" in relation to the direction of the latter. The molecules of air, in striking against this slanting surface, exert a thrust thereon which, as is shown by calculation and proved by experiment, is perpendicular to this surface, and tends to lift it. This is one force to which the apparatus is submitted. There is a second, which tends to cause it to fall towards the earth; this is its *weight*, which acts vertically from top to bottom. And finally there is another; this is the *tension of the cord*, the resistance of which acts as a check against the thrust of the wind. The pressure, resulting from the action of the current of air upon the surface of the kite, divides itself into two elementary actions. One is directed from bottom to top, and combats directly the thrust of the weight: the direction of the other is opposed to that of the retaining cord, and is therefore always destroyed by the latter, which one concludes to be sufficiently resistant as not to break under the effort to which it is subjected.

Under these conditions, the contrivance is in equilibrium. Let one of the above forces be varied, and equilibrium is disturbed immediately. If the wind increases, its pressure becomes stronger, the vertical thrust is augmented, and the kite rises. If, on the contrary, the wind does not change, but the weight of the apparatus is enhanced unexpectedly, as, for instance, by rain, the kite falls. Lastly, if the third force is annulled, that is, if the cord breaks, the kite is carried away by "the wind."

Such is a very simple example of an apparatus, which lifts itself by utilising two forces: (1) the resistance of the air; (2) the tension of a cord, which maintains the surface exposed to the wind. Of course there *must* be a wind to lift the kite. Now there are some days when the wind is a negligible quantity. What is to be done then?

Children, the traditional fliers of the kite, do not allow such a small trifle to stand in their way. There is no wind? Well, "they create one," by running as quickly as their legs will carry them, for it must not be forgotten that wind is not a concrete factor! It is the *relative* movement of the air in comparison with a body, and this movement may take place, either with the air in motion and the body stationary; or with the air still and the body moving rapidly through it. This is the reason why in a motor-car one has a sensation of "wind" even when there is none. And children, by following these instinctive actions, invented and realised the *aeroplane*.

SCIENTIFIC KITES: MILITARY KITES: KITE ASCENTS

We do not intend to give in detail the technics, construction, and launching of the kite. But it is impossible to ignore two of its applications which are of the highest value, the one to science, the other to war. These are exploring and military kites respectively.

When it is a question of investigating scientifically the uppermost atmosphere, "sounding balloons" carrying self-registering barometers and thermometers are sent aloft. These balloons can rise to extreme altitudes; they have attained heights between 18,000 and 20,000 metres. But they are liable to be lost, to fall into desert regions whence they can never be recovered.

When it is desired to ascertain the temperature of the air in other than the very highest regions, when an altitude of from 4000 to 5000 metres is sufficient, one can use kites formed of several flat surfaces connected together. It will be noted that we find this arrangement in the biplane.

Self-registering meteorological instruments, photographic appliances, &c., can be attached to this apparatus, which after being sent up is held, not by a cord, but by a thin steel wire seven or eight tenths of a millimetre in diameter. Such a wire can withstand a strain of nearly 50 kilogrammes without breaking. Kites so equipped, and flown by Prince Albert of Monaco over the Atlantic from the deck of his yacht *Princess Alice*, attained an altitude of 4500 metres, recording most valuable results concerning the temperature and humidity of the upper atmospheric strata.

But it is possible to go farther. We can imagine the ambition of an observer to lift himself by the aid of a kite. As a matter of fact, in France, two distinguished officers, Captains Madiot and Sacconey, have carried out some very fine experiments in the course of which they lifted themselves with a success which was equalled only by their intrepidity.

However, this idea is old; the earliest attempts date from a long time ago. The French sailor Le Bris made the first venture in 1856; Maillot followed him in 1886. But it is through the efforts of the English and Russian officers that we are able to say that ascent by kites is now an accomplished fact.

We may confine ourselves to the mention of the names of Hargreaves (1894), Baden-Powell (1894, 1896, 1898), Lamson (1896), Wise (1897), in England, and above all of the Russian Lieutenant Schreiber, and the English Captain Cody, two designers of military kites.

In this case, several kites are used, their sustaining efforts being led to a single cable to which the "car," in which the observer desirous of being lifted takes his position. The lines on which such a "train" of kites are disposed and manœuvred differ according to the various operators.

After all is said and done these experiments are of the greatest interest to aviation, and they support that apt expression of the unfortunate Captain Ferber, "A kite is nothing more than an anchored aeroplane."

DEFINITION AND ELEMENTARY EQUILIBRIUM OF THE AEROPLANE

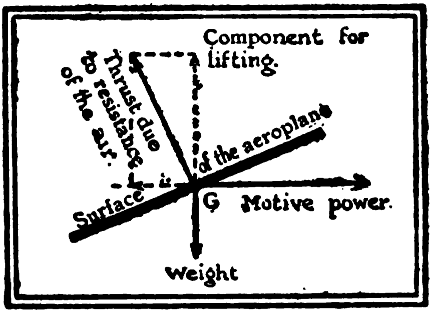


FIG. 43. Equilibrium of the theoretical aeroplane

The aeroplane is kept in equilibrium under the combined forces of its weight, power of its engine, and of the resistance of the air

An aeroplane, in fact, is nothing but a kite which "creates its own wind." For this purpose the string is replaced by a motor, and a screw which imparts a speed equal to what the wind would have to be to support it like a kite, were it held by a cord. The *pull* of the string is replaced by the *thrust of propulsion* (Fig. 43), and the conditions of equilibrium are, at least fundamentally, quite as simple as those of the kite. An aeroplane in principle therefore will be composed of a *supporting surface* divided into one or two parts, which are often called the *wings*, attacking the air in an oblique manner by means of a *propeller* and a *motor*. It will be connected to a *skiff* or *car*, in which will be the aviator, the motor, and the mechanism for steering, comprising at least two "rudders"—one a "steering rudder," to turn to right or left, and the other an "elevator," for ascending or descending.

The motive power propelling the apparatus, the surface of which cuts the air in an oblique manner, compels the gaseous molecules to glide under this surface. Therefore, they exercise a *resistance* upon it, the effect of which is a perpendicular *thrust* upon the moving plane. This thrust may be replaced by two other forces; one vertical, which tends to lift the contrivance, by annulling the effect of its *weight*, which would tend to make it fall; the other, horizontal, directed towards the stern, and tending to retard the speed of the apparatus. Therefore equilibrium is realised when the speed due to the motive power is sufficient for the thrust to be able to lift the weight of the apparatus. Thus this speed is called the "controlling speed," and the aerial vehicle will continue its travel in a straight line so long as the forces which act thereon retain their relative values.

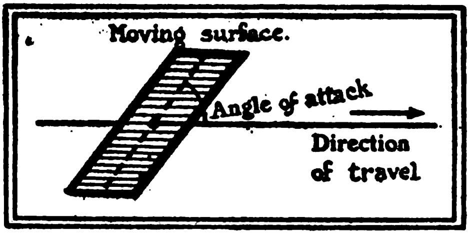


FIG. 44. Resistance of the air upon a slanting surface

But if any one of the considered forces should change, the equilibrium is destroyed immediately. For instance, if the speed of propulsion increases, the resistance also increases, and also therefore the resultant vertical lifting component. The weight not varying, equilibrium is destroyed and the apparatus rises; on the contrary it descends if the speed of propulsion decreases; it descends also if the "supporting surface" for some reason or other is diminished, in the same manner as it rises, if the weight of the apparatus is lessened, as occurs during a journey, owing to the consumption of fuel by the motor.

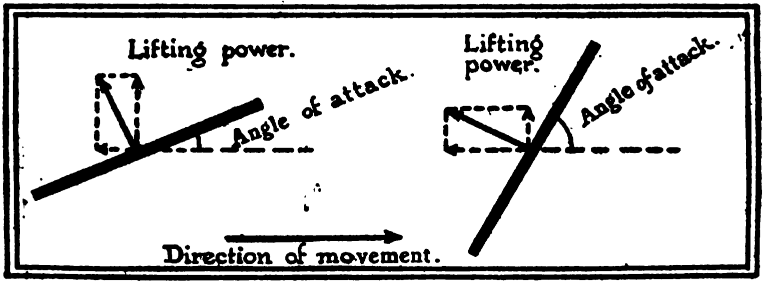
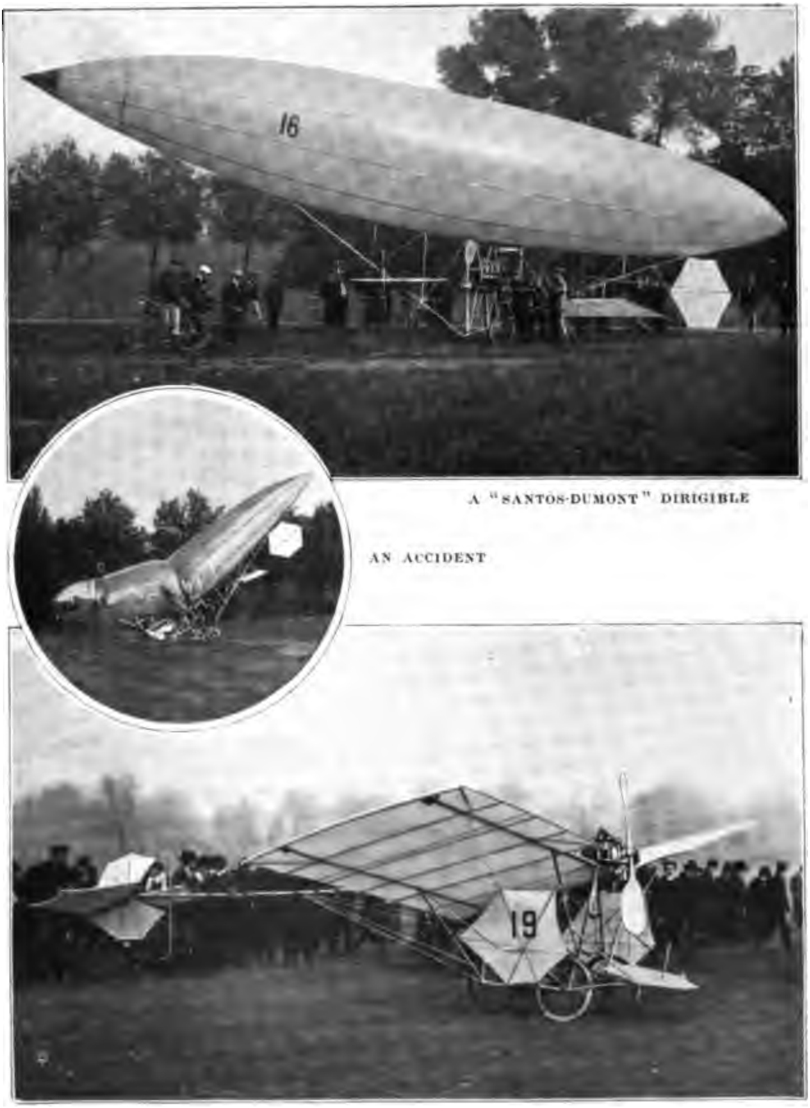


FIG. 45. Influence of the angle of attack

The vertical lifting thrust increases as the angle of attack is decreased

Therefore, the very simple conditions of equilibrium which we have examined are precarious, and the problem must be investigated a little more closely to seek the conditions answering the requirements of current practice.

PLATE XXIII

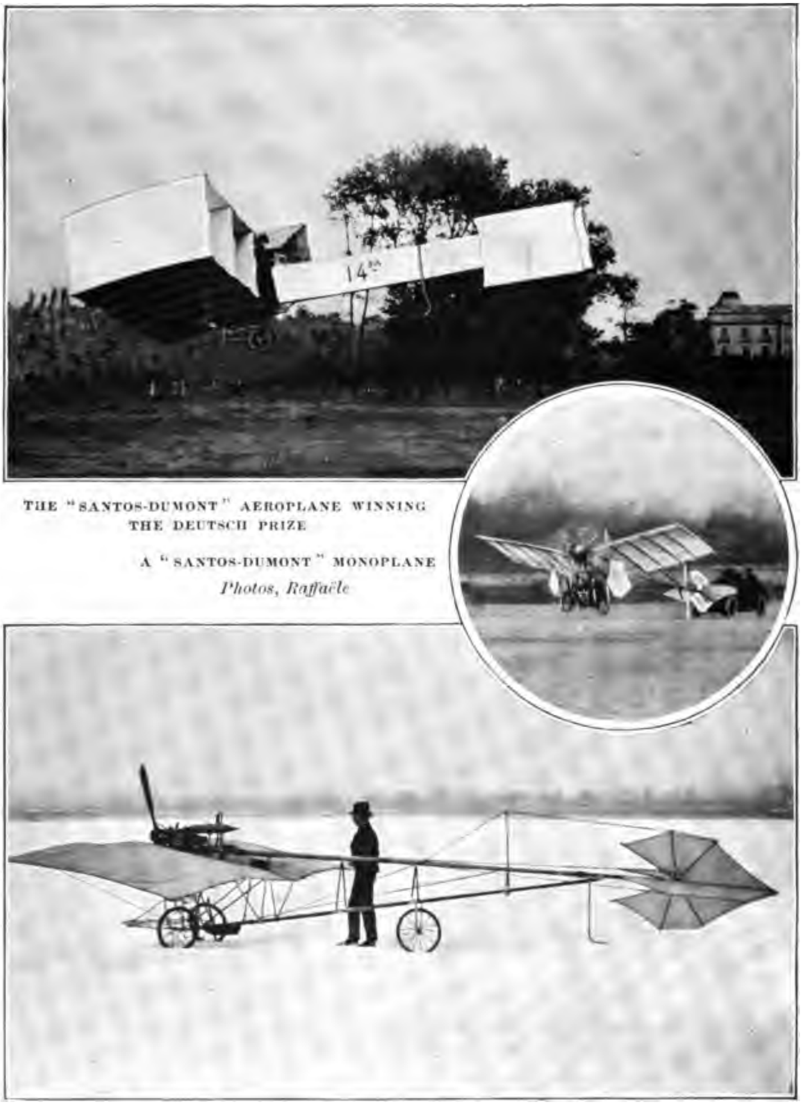


A "SANTOS-DUMONT" DIRIGIBLE

AN ACCIDENT

Photos, Raffaele

THE LITTLE "SANTOS-DUMONT" AEROPLANE



THE "SANTOS-DUMONT" AEROPLANE WINNING THE DEUTSCH PRIZE

A "SANTOS-DUMONT" MONOPLANE

Photos, Raffaële

Photo, Branger

SANTOS-DUMONT'S "DEMOISELLE"

RESISTANCE OF THE AIR : ANGLE OF ATTACK : CENTRE OF THRUST

To learn exactly what will happen when the controlling speed is varied, we must hearken back for a moment to the laws of the resistance of the air, which are fundamental in the question of aviation.

Let us consider (Fig. 44) a moving surface, inclined in the direction of its advance. The resistance of the air increases proportionately to the spread of this surface, in proportion with the square of the speed at which it is driven, and increases at the same time as the angle at which it is inclined to its trajectory, and which is called the angle of attack. Consequently, if this angle is very small, the resistance is very slight; but on the other hand, the lifting effort is a greater proportion of the thrust (Fig. 45, No. 1), whereas the resistance to advance is a fraction less. If the angle of attack increases (Fig. 45, No. 2), the thrust becomes stronger immediately, but the proportion of this thrust, which constitutes the lifting effort, decreases if more inclined to the vertical, whilst resistance to advance is increased. Therefore it is necessary to seek the *optima* value of the angle of attack. Calculation and experience agree that it must be very small always.

But a more uninterrupted study of the resistance of the air upon an inclined surface in motion, shows us something even more important. We have supposed, in the elementary explanation which we have given of the conditions of equilibrium of an aeroplane, that this was absolutely symmetrical, and that all the forces which acted upon it were applied to a common point G, which would be its *centre of gravity*. In practice, things are not so simple.

In reality the point of the moving surface where the pressure is applied, a point which is called the "centre of thrust," does not coincide with the centre of gravity. It approaches nearer to the front edge of the moving surface, as the angle of attack is decreased. This is what experiment demonstrates: if one moves forward through the air in a horizontal direction, a perpendicular plane which cuts the molecules squarely (Fig. 46), the phenomena are symmetrical, and the thrust will be exercised upon the centre of gravity itself. But if the moving plane is inclined (Fig. 47), the gaseous molecules have much greater difficulty to rise up under the cutting edge than to go downwards to gain the other side of the plane. Then the thrust is greater on the front extremity up which they are forced to travel, and the centre of thrust comes nearer the front edge.

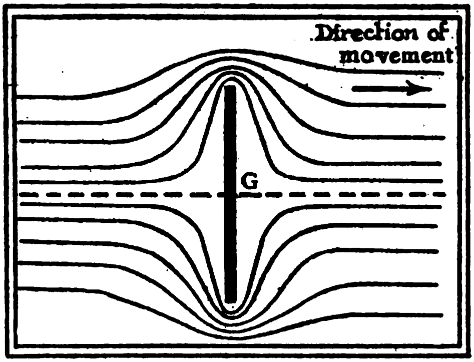


FIG. 46. Flat perpendicular surface advancing horizontally through the air (*the air molecules glide symmetrically round the ends*)

Such fluctuation in the position of the centre of thrust alters the aeroplane's conditions of equilibrium and affords us some data concerning construction.

Let us consider an aeroplane advancing (Fig. 48) with a very small angle of attack. The centre of thrust, as we have just seen, will be brought forward to a point near the front edge. The lifting effort applied to this centre will be directly opposed to the weight no longer, the latter being always applied to the centre of gravity. Hence the disposition of the two forces will tend to cause the surface of the aeroplane

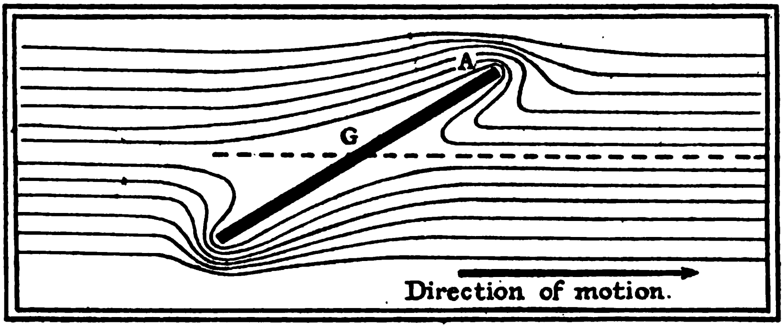


Fig. 47. Flat surface advancing obliquely through the air

The molecules of air glide by in a dissymmetrical manner, and the thrust of the air approaches point A to turn in the direction indicated by the curved arrows shown in the diagram.

Moreover it is necessary to observe that the position of the centre of thrust is not fixed; it varies for each value of the inclination of the aeroplane, and advances more towards the front as the angle of attack is made sharper. Yet this is not all. Let us suppose, through an accident or some untoward mishap during travelling, that this surface is inclined excessively. The air would then strike from above, and this would bring about a certain rapid and fatal fall. Consequently a means must be found for readjusting the aeroplane when it inclines in the direction of its length. This end is fulfilled by the *empennage*.

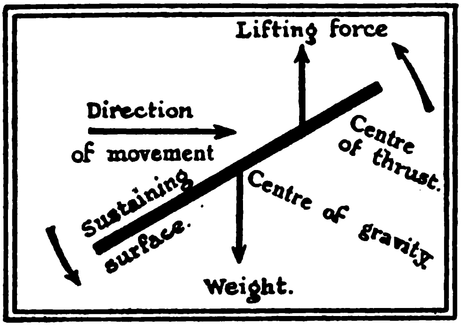


FIG. 48. Equilibrium of the actual aeroplane

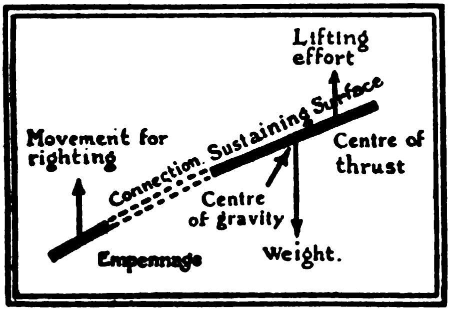


FIG. 49. Effect of the empennage

It restores the balance of the inclined aeroplane owing to the wind impinging upon the tail from below

The empennage comprises a surface placed well to the rear of the sustaining surface (Fig. 49), to which it is joined by a "connection" which, being light, rigid and latticed, offers only a slight resistance to the air. Under these conditions, when the influence of the thrust is applied forward of the centre of gravity, where the weight acts, the aeroplane, as shown in Fig. 48, tends to turn in such a manner that its stern is lowered towards the ground. But the thrust which is exercised upon the empennage, a thrust acting with the aid of the long "lever arm" represented by the rigid connection, lifts and brings the apparatus back to its normal incline, in accordance with the calculations concerning its dimensions and motive power. In the same manner a projecting "flange" (Fig. 50) not very high, towards the stern of the sustaining surface, would be "effaced" behind the front edge during the journey under a normal incline. But if the apparatus were declined at the bow, the air striking this flange, which would be exposed by the accidental lowering of the front edge, would act thereon, and this pressure, bearing on the stern, would force it down, restoring the aeroplane to its normal incline. It may be seen, therefore, from these two examples that an aviation apparatus can be given an automatic longitudinal stability.

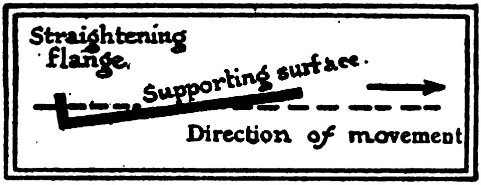


FIG. 50. Effect of a vertical stern "fringe"

Let us remark that kites have been fitted with this very simple means to secure longitudinal stabilisation for a long time past in the form of a *tail*. This does not serve merely as a counterweight to the stern; a piece of lead at the bottom of the frame would answer this purpose, but without ensuring stability. The tail acts as a true stabilisator, and kites *must* be provided therewith. However, we shall return to this subject in the course of the next chapter. There is one other question, also vital in balancing the aeroplane; that is transversal stability. But in this question, the shape of the wings, dimensions, even the construction of the apparatus, are inferred as being known. We will conclude this explanation of the general principles, and see how they are applied to the conception of a projected flying machine.

CHAPTER II

APPLICATION OF THE GENERAL PRINCIPLES

FROM THEORY TO PRACTICE : THE WINGS : MONOPLANE OR BIPLANE : STABILITY AND THE MEANS FOR ITS REALISATION

SHAPE AND DISPOSITION OF THE WINGS

WE have seen by what effects of the resistance of the air a flying machine may be sustained in the atmosphere. We must now ascertain in what manner we can utilise these effects most advantageously.

First of all, should we use flat or concave wings? This is the primary question. If we take as an example the wings of a bird, which are the sustaining surfaces for soaring, we notice that they are always concave underneath. Since the first attempts at aviation, constructors, therefore, have sought always to build wings distinctly concave, the concavity being turned towards the earth. Experience has shown, moreover, that a surface slightly concave towards the rear gives the aeroplane, for the same speed, much superior lifting power to that obtainable from a flat surface carried thereto. Further, M. R. Soreau, in a very fine calculation, has shown that for any concave wing a flat surface may also be determined. Such would act as if it were connected rigidly with the concave surface, while the carrying power would be just the same as that of the concave surface. But, at the same time, the concavity introduces a "counter-resistance" to advance, *i.e.* produces a force of reaction which increases somewhat the propelling effort in the same direction. In other words a slightly concave surface "carries" better than an equivalent flat surface.

Calculation and experience being in agreement in the recommendation of concave surfaces, we shall employ such in the construction of aeroplanes.

Moreover, the wings will be elongated and disposed at right angles to the length of the flying body.

For this purpose imagine a wing of rectangular shape, measuring 2 metres by 4 metres, viz., 8 square metres (Fig. 51). If we cause this surface to advance longitudinally, the streams of air struck by its front edge, and driven beneath the wing, will escape under the edges to which they are in close proximity, and will contribute no longer to sustentation. If, on the contrary, this same wing be moved on its broader edge (Fig. 52) the currents of air cannot escape sideways, because they are pressed back by their neighbours, with the exception of those which are at the extreme sides. In this second arrangement, all the currents thus contribute to sustentation. Our wings, which we have been induced to make slightly concave, will therefore be disposed transversely.

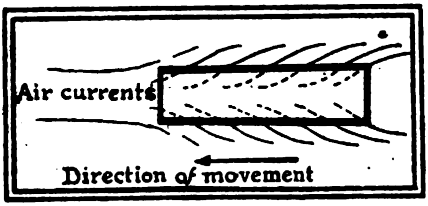


FIG. 51. A long, narrow, flat surface

The currents of air escaping immediately along the sides are inefficient for sustentation

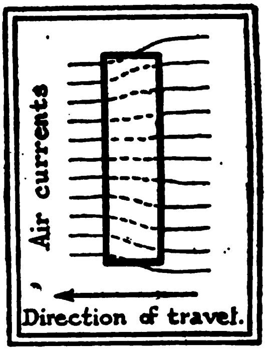


FIG. 52. A short, wide surface

The currents of air are kept beneath the surface during the movement, and are therefore able to sustain the plane

This lateral arrangement of the supporting surfaces, moreover, is what we find in all birds and flying insects; in birds particularly the "spread" of the wings is always considerable (Fig. 53).

In addition, irrespective of the extent of this spread, the carrying surfaces may be set either horizontallly, in the form of a more or less obtuse angle, or like a very open upright, or overturned V. The V-arrangement of the wings has been adopted, notably by Captain Ferber, while on the other hand the wings of the Wright machine are straight.

MONOPLANES AND BIPLANES

We are led, by virtue of what has been said, to take light sustaining surfaces of great superficies if we wish to raise an appreciable weight, such as, for instance, a motor, propeller and aviator. Let us suppose that calculation as a result of experimental data shows us the necessity of a carrying surface of 50 square metres. Will this surface have to be employed in the form of a single transversal wing, of two, or even of three wings superimposed? Under these conditions the transversal "spread" is decreased, which, as regards the encumbrance of the apparatus and its working efficiency, may constitute an advantage. In other words, shall the aeroplane be "monoplane" or "multiplane"?

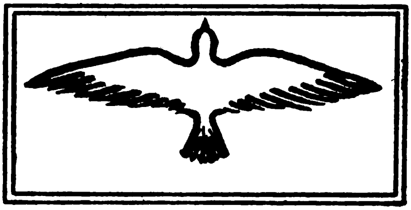


FIG. 53. A bird's wings outspread

The wings act as supporting surfaces and the tail serves as the empennage

Birds obviously are monoplanes, and they are excellent monoplanes too. Consequently everything would urge us to make our aeroplanes as monoplanes. But there are kites to recommend multiplanes, or at least biplanes; and the indications of this popular toy cannot be overlooked, for, as Captain Ferber so truly said, "the kite is an anchored aeroplane." In fact, if the ancient kite is a monoplane with the "tail" constituting the stabilisating empennage, the modern kite is at least a biplane. The following will show how and why this disposition has been adopted, and which experience has shown to be very advantageous.

Let us consider a kite (Fig. 54 A) which we send aloft in a very steady wind. So long as we do not seek too great a height, the apparatus will behave beautifully. But if we wish to send it higher and higher we must not forget as we pay out the cord that the kite has to support a proportion of the ever-increasing weight. Therefore there will be a height limit above which the weight of the paid out cord will exceed the carrying effort, resulting from the thrust of the air upon the membrane of the kite, and the latter will fall. But an arrangement, as simple as it is old, can be employed now. An auxiliary kite may be introduced and attached at an intermediate point of the main kite cord, and will thus support a proportion of the cord's weight. Such a combination will be able to rise to a much greater height than a single kite. The two kites may be placed a short distance apart, or be brought very close to, and parallel with, one another (Fig. 54 B), or they may be so made up as to form boxes covered with cloth. It is upon these lines, laid down by Hargreaves the Australian, that the modern children's kite (Fig. 54 C) is built; also those, larger and more skilfully constructed kites, which are used by meteorologists for carrying registering instruments into the upper atmosphere.

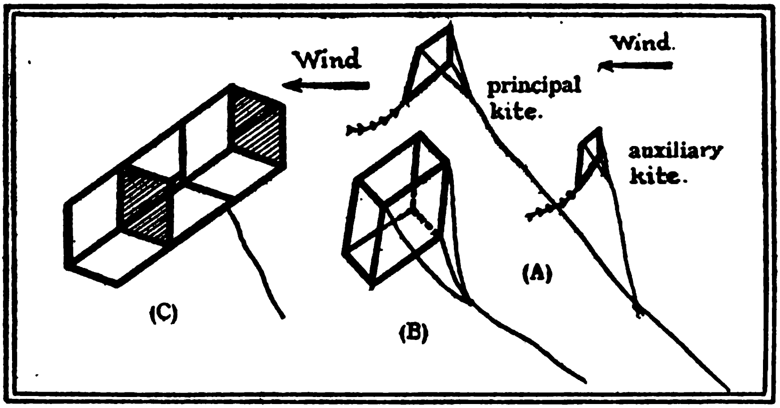


FIG. 54. Evolution of the box, from the multiple, kite

The two planes of the kites spaced apart in the system A are brought together and combined in the system B; while in C two groups of parallel surfaces, connected together by a rigid framework, resemble the biplane in the general lines

The "cellular" kite (Fig. 54 C) is nothing but a biplane aeroplane, provided with an "empennage tail," to secure its stability.

Therefore we can distribute our supporting surface upon two superimposed parallel planes. Such is the design of the Farman, Delagrange, Wright, and Voisin aeroplanes, whereas those of Blériot, Esnault-Pelterie, Gastambide, Santos-Dumont, and the "Antoinette" are monoplanes. Naturally, we can make triplanes or quadriplanes, but one must not proceed too far in this direction, as there would result a "pile of planes," the stability of which would be precarious. Here, as in all things, the happy medium must be found. One inherent objection to multiplane construction must be pointed out; the rigid supports which connect the planes together present a large surface of resistance to the air, and for this reason monoplanes are much to be preferred. Moreover, the Reims week of 1910 demonstrated conclusively the superiority of the monoplane, which appears to be the aviation apparatus of the future.

LATERAL STABILITY : TURNING

We have obtained longitudinal stability in the aeroplane by the use of the "empennage tail." But lateral stability must be secured also. In other words, the wings of the apparatus must not incline from right to left, or *vice versâ*, during travel. At any rate, if such an incline were perchance to occur, the apparatus must be constructed in such a way that it rights itself under its own effort.

Now, an aeroplane must be considered in two phases of movement—that following a straight line and that following a curved line, otherwise called "turning."

In the case of the straight line movement, the lateral stability, if not ensured, is fulfilled very adequately at least by the spread of the carrying surfaces, which counteracts sudden inclination. Moreover the centre of gravity of the contrivance is always below the carrying planes (or the single surface equivalent thereto) on account of the weight of the motor and passenger, a weight which would tend to right the apparatus if it were to incline unexpectedly.

But this is no longer the case when, describing a curved line, the aeroplane turns. Then there intervenes a complex phenomenon which causes it to dip "inwards"—that is to say, towards the centre of the circle which the machine describes. This phenomenon is the unequal resistance of the air upon the two extremities of the supporting wings. We must examine this a little more minutely.

Let us consider an aeroplane (Fig. 55) describing a turn. To gain a clear idea of the subject, let us suppose that the spread of this aeroplane is 10 metres, and that the circle which the centre of the machine itself describes has, for instance, a radius of 15 metres. Under these conditions it will be seen that the inner extremity, A, of the wing will describe, during a certain time, the arc of the circle AA′, in passing from position (1) to position (2), whilst the outer extremity, B, of the same wing will describe, *during the same time*, the arc of the circle BB′, double the length of AA′. The exterior extremity, B, therefore must travel twice as far during the turn as the interior extremity; that is to say, move at twice the speed of that of the inner edge, A. Now, as the resistance of the air is proportionate to the *square* of the speed, the result is that the interior extremity, A, moving less quickly, will be subjected to a lesser resistance from the air, and therefore will be less "sustained" by the air than extremity B. Consequently, *while turning, the aeroplane must incline itself more and more towards the centre of the circle which it describes, as the radius of the turn is decreased.*

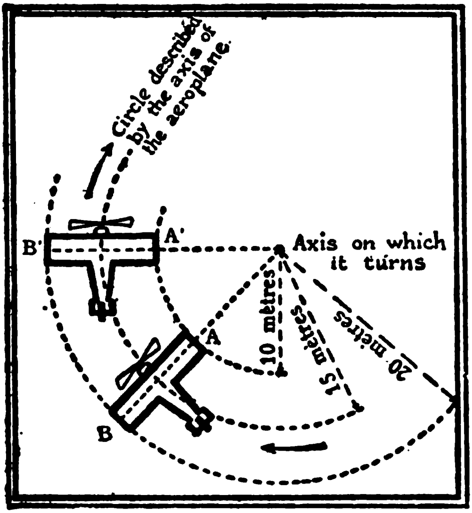


FIG. 55. How an aeroplane turns

The resistance of the air upon the inside wing being reduced, transverse equilibrium is destroyed, so that the aeroplane inclines towards the centre of the circle represented by the turn

We can confirm this by means of figures, and in a very simple manner. If the speed of the outer wing is 20 metres per second, that of the inner wing, in the example we have taken, will be only 10 metres. The lifting efforts will therefore be no longer equal, but will be between them in the proportion of the square of 20 with the square of 10—that is, in a proportion of 400 to 100. It may be seen, therefore, to what degree the equilibrium will be destroyed. It is true that an aeroplane may never have to make so "sharp" a turn, but we have selected an extreme example purposely. Such always exists, so lateral incline must be guarded against absolutely while turning.

This natural incline, however, has its advantage; it counteracts *centrifugal force* appreciably. The latter is unavoidable in any curvilinear movement, and is of greater moment in the aeroplane inasmuch as its surface of lateral resistance is weaker. Major P. Renard actually proved that inclination of the aeroplane was essential to combat centrifugal effect. This inclination lowers the trajectory. Therefore, aviators should rise slightly before making a "turn," if subsequently they desire to maintain their altitude.

PRACTICAL MEANS OF PREVENTING LATERAL INCLINE: "AILERONS," PARTITIONS, WARPING

At all events, it is indispensable to keep the carrying surface as horizontal as possible throughout the trajectory, whether it be rectilinear or curvilinear. Several means may be utilised to this end.

First of all, there is a very simple one, which I am surprised at not having seen used experimentally, or at least tried, since it seems very feasible to me. Since "lateral inclination" is a result of unequal resistances on the two extremities, why not equalise these resistances? We cannot prevent speeds from being unequal while turning, but we can vary the supporting surfaces inversely; we can increase the surface at the "inner point" A (Fig. 55), and decrease it at the outer point B. For this purpose it would suffice to fit to the extremity of the wings, varying surfaces, either arranged in the form of a fan and able to fold up in the same manner as a bird's wings, or of sliding ribs, one withdrawing a certain distance beneath the extremity of the outer wing, and the other projecting to twice that distance from the extremity of the inner wing. The surface of the inner wing which dips would thus be increased, while simultaneously that of the outer wing which rises would be decreased, and it would reduce the difference from the thrusts—that is, the cause of the inclination. These two movements could be produced automatically by a simultaneous movement of the steering rudder.

The celebrated American aviators, Wilbur and Orville Wright, have adopted another arrangement—"warping of the wings." The following explains in a few words how this is done.

The extreme angles of their aeroplane can be turned up or down (Fig. 56) just like the "corner" of a visiting card. As the Wright aeroplane is a "biplane," wooden battens disposed one above the other lift up the corners at the same time, so that when a corner of the upper wing is lowered the corresponding corner of the lower wing is depressed also. The action is controlled by a manœuvring lever pushed or pulled by the aviator, and when the corners on the left are forced down those on the right are forced upwards, and *vice versa.* Under these conditions, it is easy to see how this arrangement enables lateral inclination to be overcome. A turn is made, and the aeroplane has a tendency to incline inwards; but the aviator immediately manœuvring his lever, lowers the corners on the inside of the turn and elevates those on the outer edge. And then, as is shown in the diagram, the effect of the air on the corners thus offered to its action rights the apparatus.

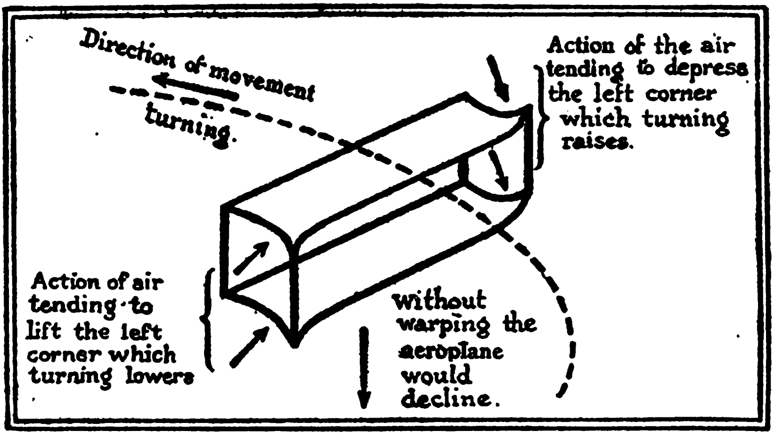

Direction of movement
turning.
Action of the air tending to depress the left corner which turning raises.
Action of air tending to lift the left corner which turning lowers
Without warping the aeroplane would decline.

FIG. 56. The Wright principle of warping the wings

The warped corners strike the air, the resistance of which depresses the upturned corner, and elevates the lowered corner

M. L. Blériot, the French aviator, evolved and adopted on his aeroplanes some time ago—long before the arrangements of the Wright Brothers had become known—a very reliable system, quite as ingenious and far simpler, which does not require the wings to be deformed by warping. There is at each extremity of the fixed wings of his aeroplane, a small subsidiary moving wing, "Aileron" (Fig. 57), capable of being inclined in relation to the surface of the wing by moving upon a horizontal axis. When turning the aileron on the inside is lowered while the outer aileron is raised. The effect is the same as warping the wings, but this arrangement has the advantage of not bringing about any elastic deformation of the frame, which, unavoidable through warping, must inevitably end in endangering the essential solidity of the structure. Many vessels of the *Antoinette* type are fitted with this arrangement, which is excellent from all points of view.

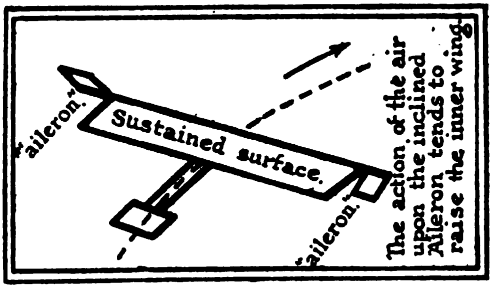

aileron
Sustained surface.
aileron
The action of the air upon the inclined Aileron tends to raise the inner wing.

Fig. 57. Blériot's correcting ailerons

These ailerons strike the air, which lowers the upturned aileron, and elevates the depressed aileron

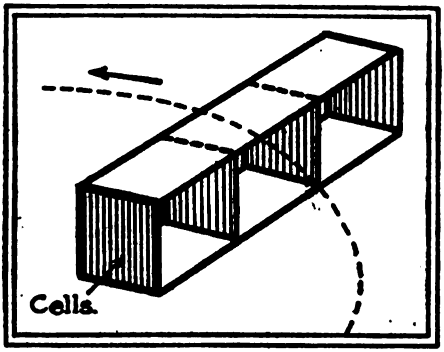


Fig. 58. The Voisin partitioning system

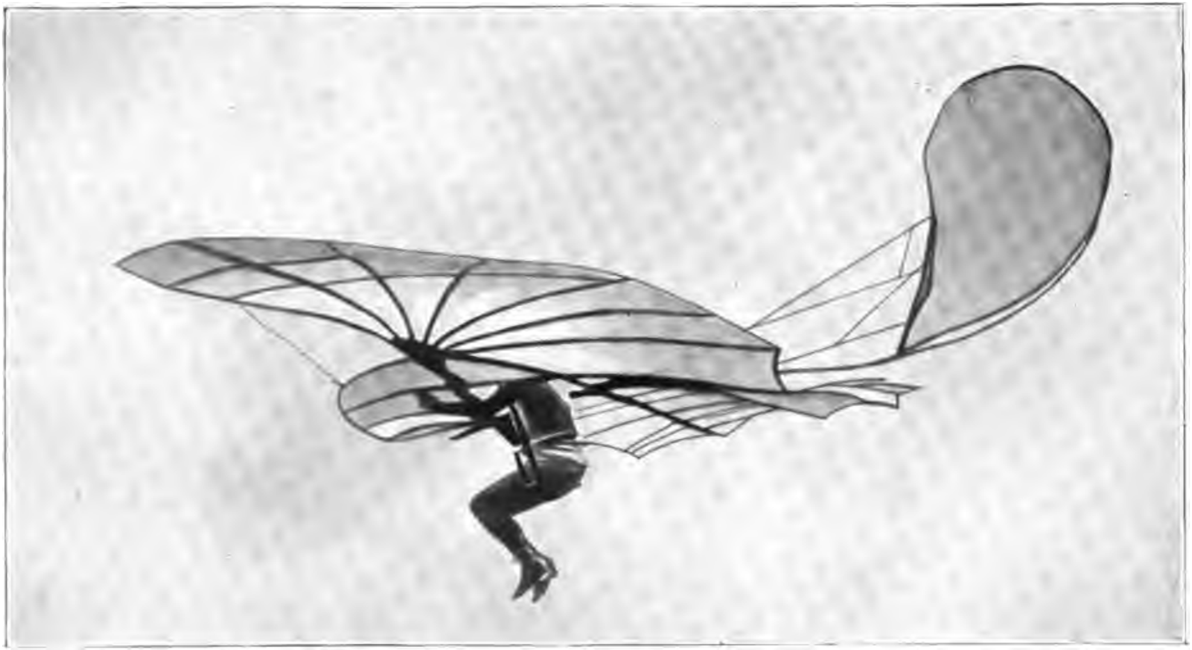
The vertical surfaces oppose "drift"

These various arrangements for righting are governed by the aviator. Therefore it is necessary for him to bring about the readjustment of the apparatus; to perform a special movement, completing that which he makes in steering to right or left when manœuvring the machine by the rudder. But search has been made for an *automatic balancer* independent of the helmsman, but brought into play by the aeroplane itself. This solution has been offered in a simple manner by the Voisin Brothers, the French constructors who built the aeroplanes made famous by the exploits of the aviators Farman, Delegrange, and Rougier. The arrangement employed by them is "partitioning" (Fig. 58) and applies to multiplane aeroplanes. It comprises the introduction of rigid vertical partitions between the two parallel carrying surfaces. These partitions, owing to the resistance they offer to the air, oppose any deviation arising from centrifugal force, so that lateral inclination is practically eliminated. The aviator, owing to this principle of construction, no longer has to trouble about his equilibrium: he only has to think of steering. Let us remark, in passing, that although it is true that the auxiliary surfaces of the partitions add a little weight to the apparatus, they do not increase, at least to any significant degree, its resistance to advance, inasmuch as they cut the air with their edges, and are set in the direction of travel. Although this system does no more than make the machine a little heavier, this is a distinct drawback to present-day aviation. Hence there is a tendency to revert more and more to the ailerons or to warping. In the latest French biplanes the partitioning is abandoned in favour of ailerons.

Lastly, there is "artificial" balancing obtained by the stabilisating mechanism bringing into action forces other than the resistance of the air. This type of balancer is the *gyroscope*.

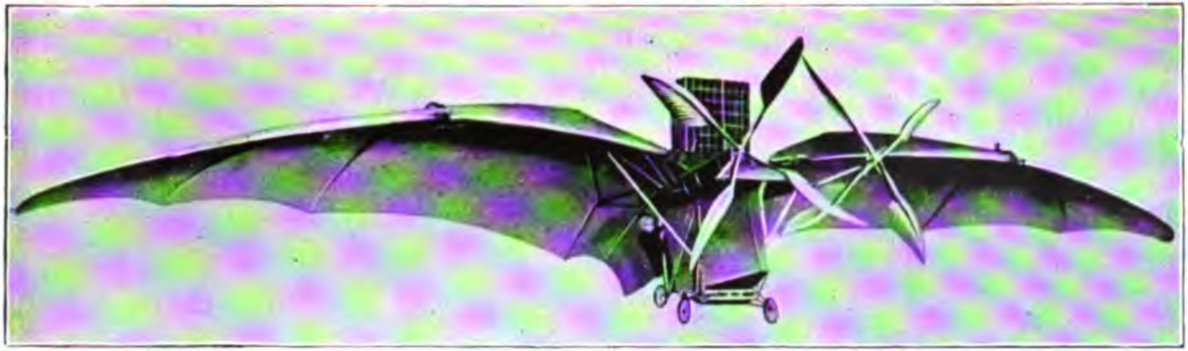
Every one knows those toys—"gyroscopical tops"—which once started at full speed maintain their balance on a point or on a thread, appearing to defy all the laws of gravity and equilibrium. These gyroscopes, discs with a heavy periphery, have the important mechanical quality of being caused to deviate only from the plane in which they are rotating with great difficulty and at the expense of a very great effort. The extent of the latter to bring about deviation becomes greater as the turning mass is increased, and its speed augmented. If, therefore, a gyroscope is mounted on an aeroplane and its rapid rotary movement is maintained by a motor, an effort is necessary to change the rotating plane forming part of the frame of the aerial vehicle, and one may hope thus to obtain lateral stability in an automatic manner. Theoretically this idea is excellent. In practice it is another matter.

PLATE XXV

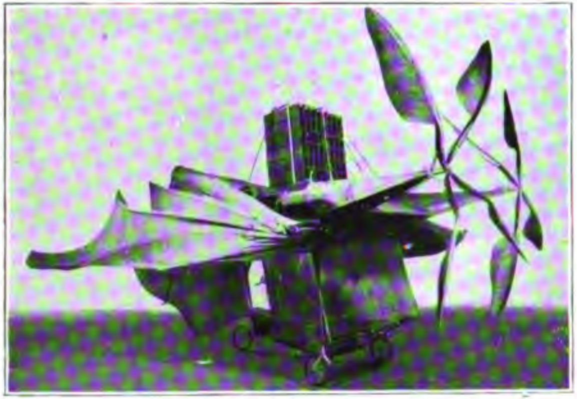


A PIONEER. THE GERMAN EXPERIMENTER, OTTO LILIENTHAL, MAKING A GLIDE

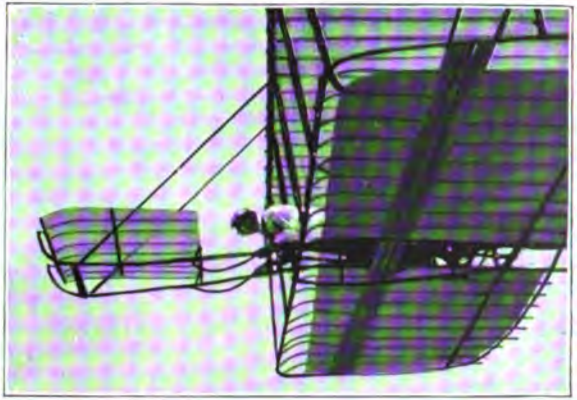
PLATE XXVI



M. ADER'S "AVION," THE FIRST AVIATION APPARATUS TO RISE INTO THE AIR *Photo, Malcuit*



THE "AVION" WITH WINGS FOLDED



WRIGHT MAKING AN AERIAL GLIDE

In the first place, a gyroscope when constructed on a large scale becomes a very dangerous apparatus. Let it escape from one of the bearings in which the points of its axis revolve and it becomes a destructive projectile both of men and everything else. Serious accidents have happened already from this cause. In the second place, in order to be efficient, it must be fairly weighty, and in the matter of aviation, weight is a very vital factor.

Then—and here is the greatest theoretical objection which can be urged against its use—it might, if it worked efficiently, compromise the solidity of the light framework constituting the aeroplane. In fact, what causes the aeroplane to incline, is the effort resulting from the action of air resistance bearing *upon all parts* of its long surface, whereas the gyroscope only acts at one single point of its framework. It is, therefore, supposing this means of balancing to be efficient, as if one of the points of the aeroplane were pinched in a vice and an inclining effort exercised upon the rest of the fabric. What would happen then? Twisting would occur which might jeopardise the solidity of the structure. For this reason, it seems to me that the gyroscope would be dangerous if it really acted; and if it should be inoperative it would be a dead weight, useless to haul about in the air. But all this is only theory, because experiments alone, frequently repeated, will be able to supply us with really reliable data on this point.

Let us add, that the use of a double rudder at the bow and stern, moving in opposite directions, has been suggested in order to improve balancing.

So far experiments have not been sufficient to decide the practical value of this arrangement. Another means of automatic balancing, evolved and tried a short while ago, comprised automatic variation of the "angle of attack" by articulating the whole of the carrying wing around a horizontal axis. This wing is held in its normal position by a powerful spiral spring which resists the pressure of the air when the aeroplane is travelling at the required speed, but which succumbs to this thrust, if the speed increases suddenly, by diminishing the angle of attack. Experience will show what this ingenious conception is worth. In any case, the "natural" means of balancing are the most rational, because they act with effects similar to those of the perturbing forces of equilibrium.

STEERING : THE RUDDER AND ELEVATOR

As we have mentioned turning movement, the means by which it is accomplished must be indicated—the *steering rudder.*

The steering rudder is similar to that used on boats and dirigible balloons. It is a light, strong, thin plane, turning about a vertical axis, operated by a "wheel" or motor levers, at the will of the aviator, who can turn it either to the right or left. The rudder is placed as far as possible to the stern of the aeroplane, and away from the supporting surfaces (Fig. 59). When it is turned to the right or to the left, the molecules of air, striking its surface in an oblique manner, exercise a thrust which is all the more efficient in causing the body of the aeroplane to swerve, since it is placed at the end of a long lever. It is for this reason that the rudder is placed invariably at the rear end of the empennage tail. When it is desired to travel in a straight line, the steering rudder is brought back to the central position; that is to say, to the longitudinal axis of the apparatus, and the air no longer acting upon its surface, no horizontal deviation results.

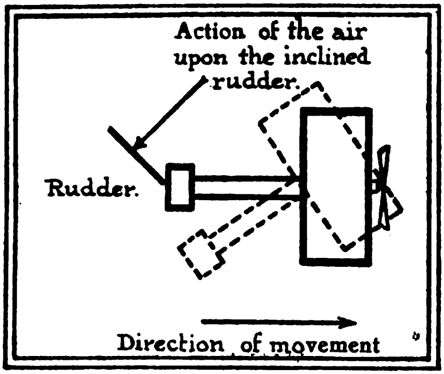


FIG. 59. The steering rudder

The air striking the rudder blade causes the aeroplane to turn in the opposite direction

The steering rudder can be efficient only if the aeroplane present a "lateral resistance to drift." An aeroplane with no opposing surface to a transverse movement, will not answer the helm. Hence, there must be a lateral surface, if represented only by the "hull" of the skiff. From this point of view, therefore, partitioned aeroplanes are really superior.

The *elevator* is a similar device, but moving about a horizontal axis, causes the aeroplane to deviate, not to the left or right, but upwards, or downwards; in other words, compels it to ascend or descend. Its operation is explained in the same manner as that of the steering rudder. This invention has been attributed to the Wright Brothers, but I believe erroneously, as Colonel Renard applied it to his airship *La France* in 1885, as is testified by the official documents published at that time, which contain a full description of the arrangement and also the explanation of its operation.

The elevator may be placed either at the bow or stern of the aeroplane: each disposition has its advocates and opponents. The Wright Brothers have placed it at the bow, and as people "went a trifle mad" on everything associated with their name, it was concluded to be "imperative" to carry the elevator in front. But Messrs. Esnault-Pelterie, Blériot, and the constructors of the *Antoinette* aeroplane, to cite only these gentlemen, instal it at the stern.

LAUNCHING THE AEROPLANE

Every one knows that principle of reasoning, extensively used in geometry, which commences, "Let us suppose the problem as solved."

Present industry offers us a variety of machines which, if I dare so to express myself, "can only go when they are already going." There is, for instance, the explosion motor, which must be "started up" with all one's might to set it in operation so that it may attain its normal speed.

The aeroplane is a new example of this method of procedure. The conditions of equilibrium suppose its being in flight: stationary, it remains on the ground. Therefore it must receive an initial impulse, which "launches" it into the atmosphere, and imparts to it that speed which, owing to the molecules of air gliding under its oblique wings, first lift and then sustain it.

There are two ways of carrying out the launch. One may seek to endow the aeroplane with self-starting means. On the contrary, it may be launched artificially with the help of a contrivance remaining at its point of departure. Such launching is easy, but the apparatus, if it lands, cannot restart; it must return to a point equipped with launching apparatus, under penalty of being condemned to rise no more into the air.

French constructors and aviators courageously accepted the hard conditions which an aeroplane must fulfil to be "self-starting,"and all French aviation apparatuses leave the ground under their own power. For this purpose they are mounted on a carriage fitted with bicycle wheels. This carriage must be as light and as strong as possible, since at the moment of landing it has to withstand the shock produced as it alights upon the ground, however much this may be lessened through the skill of the aviator. Then it is an additional load, varying from 50 to 80 kilogrammes, which any aviation apparatus desirous of launching itself without outside help must carry.

But there is another extra weight imposed under this condition. This is the *increase in motor power* necessary to start by a run along the ground, under the impulse of the propeller screw attacking the molecules of air. First the inertia of the motionless apparatus must be overcome, and for this the motor must give a "pull against the collar." This effort causes the aeroplane to run along the ground, with increasing speed, until the latter is sufficient to bring about the lifting of the apparatus by the action of the air striking on the under part of the wings. Once the apparatus is in the air, but little effort is needed to sustain and propel it. However, it entails the transport of a motor, heavier than is really necessary, but the extra energy of which is indispensable for starting purposes. This additional weight, in conjunction with that of the carriage, compels "self-starting" aviation apparatuses to carry an excess of weight which may vary from 100 to 150 kilogrammes.

The conditions governing "artificial" launching such as is practised by the Wright Brothers are quite different. Freed from the severe foregoing handicap, the American aviators have requisitioned the fall of a weight to obtain the effort necessary to start their apparatus. To avoid any extra weight, even that represented by the wheeled carriage, they glide their aeroplane along a "rail."

The launching weight idea is ingenious and effective, as it must impart to the aeroplane an increasing speed. Now the falling speed of a weight increases exactly in proportion with time; this is the first law concerning the fall of bodies. Consequently, this weight, in its fall, by a rope and return pulley system, draws the aeroplane along, and consequently imparts a speed which increases steadily. Relieved of the extra weight of 100 kilogrammes at least required for "self-starting," the aeroplane thus launched can use an ordinary automobile motor, only a little heavier than the racing types, but working more steadily, instead of the extra light motors used in French aeroplanes, wherein everything being sacrificed to lightness, there may be defects sometimes, especially in regard to endurance. Thus the American aviators are placed in a better position, and have been able to accomplish feats which possibly otherwise they might not have achieved with the same facility; such flights, however, are limited, inasmuch as they must land near their launching apparatus for fear of being rendered powerless and prevented from re-starting.

THE DESCENT

When the aeroplane is in steady flight, when it is travelling at its "regulating speed," everything works normally—sustentation, advance, steering—in the manner we have explained. But the motor may stop, either through the aviator, or accidentally. Let us see now what will occur.

By virtue of its acquired speed, the aeroplane continues to advance; but, propulsion failing, the retarding resistance of the air will be felt more and more, and its speed will be diminished. Yet it must maintain the latter, but, having a motor no longer, it can only do so by descending in an oblique manner towards the earth. Here its weight will serve as the motor; by its aid the machine can be brought to the ground as gently as the aviator desires. In the descent, moreover, the steering-rudder will permit the landing-point to be chosen, and the apparatus will settle quietly. Thus, theoretically at least, an aeroplane effects a "descent," but never a "fall." This descending operation is effected readily by French aviators, who have become expert therein. It is needless to say that the greatest presence of mind is necessary to conduct an aviation apparatus;

distraction may prove fatal. With presence of mind and skill in manœuvring, "a motor failure" is no longer dangerous to the aviator; it merely interrupts his journey.

Many persons ask aviators why they do not equip their "heavier-than-air" apparatuses with parachutes. But the foregoing statements will show that this requirement is met fully. It is useless to fit a parachute to an apparatus which in itself is a most perfect parachute.

Next we will study the practical arrangements of an aeroplane destined to fulfil everyday service, possessing qualities of safety, solidity, and speed.

CHAPTER III

AEROPLANE CONSTRUCTION

WINGS AND NERVES: MOTORS AND PROPELLERS: SAFETY: WIND AND THE AVIATOR: IS IT NECESSARY TO FLY HIGH?

CARRYING SURFACES: THE "POWER OF PENETRATION"

SUPPOSING the aeroplane to be provided with a motor and a propeller as perfect as possible (we shall go further into the question of these two factors), its essential organ is the sustaining or carrying surface. This area is called sometimes the "spread of planes," and the carrying surfaces are known also as "wings." We have seen that there is an advantage in making them slightly concave on the under side. Moreover, they must be placed transverse to the line of travel, whether in a straight line or a very widely opened V. The carrying surface is formed of cloth stretched over a light and strong wooden frame. The same india-rubber fabric as serves for the construction of dirigible envelopes is used often.

But all framework is formed of members which have a certain thickness. These offer to the wind a resisting surface. Accordingly, above all things the latter must be reduced to the minimum; or, in other words, the "power of penetration" of the apparatus must be the maximum. It is preferable to have a heavy piece, representing a heavier load to be lifted and sustained, so long as its shape relative to the resistance which the air will bring to bear upon it, is well thought out.

Accordingly it will be advantageous to give the sections of the parts cutting the molecules of air fish-shaped profiles, with the larger end foremost (Fig. 60). These lines are followed in sections of the wings of several existing aviation apparatuses.

The wing framework is pisciform in section and the panels of cloth are stretched on either side of this skeleton.

For this reason it will be essential to avoid too many stretched wires, ropes, manœuvring cords extending to the exterior, and cross-pieces; and if it is remembered that biplanes cannot dispense with the latter, being necessary for connecting the supporting surfaces together, it will be seen how immense is the superiority of the monoplane over the biplane, at least from the air-resistance point of view. The latter in their various forms, in particular those of Voisin and Wright, offer to the air very needless resistance to advance, since only the carrying surfaces are efficient. For high speeds, which are the aim of aviation, I would be tempted therefore to believe in a much more brilliant future for monoplanes; those of Esnault-Pelterie and Blériot, and the *Antoinette* aeroplane already represent more than promises; their early exploits permit one to hope for still more remarkable results.

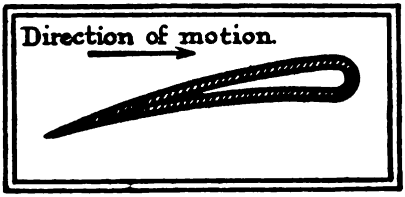


FIG. 60. Pisciform section of wings

Apart from the transverse sections, there are the nature and character of the sustaining surfaces to be considered. The fabric for the wings must be stretched upon the framework of the wings with the greatest care; seams, knots, heads of nails must not project in any way. It is imperative that the surfaces should represent, so far as possible, their geometrical definition, be of absolute continuity and regularity, and the fabric, stretched to the maximum, must be varnished also in an extremely careful manner. It is these conditions, difficult to fulfil, which render the construction of varying value, according as to how it is turned out with more or less " finish." It is perfection of workmanship which is responsible for the relatively high price of the present aeroplane; it is how the French constructors, who have carried it to the utmost limit, have acquired a reputation which gives them a superiority equivalent to an absolute monopoly.

MOTORS EMPLOYED IN AVIATION

Aeroplane motors must be light, and only the explosion motor, working with the combustion of a mixture of air and petrol gas, fulfils the indispensable reduction in weight. So far back as 1884 Colonel Renard showed that if the weight of the motor, everything included, were reduced to 5 kilogrammes per horse-power, one could realise dynamical sustentation and achieve ordinary aviation. The Colonel's previsions have been fulfilled, and even surpassed to-day, as the motor with a weight of 2 kilogrammes per horse-power is a concrete fact. In regard to the mechanical equipment, we are provided for the conquest of the air.

Nevertheless, too much must not be sacrificed to lightness. The motor, if one really wishes to "travel," must be strong and reliable. It must not be liable to heat up too much, since that demands elaborate cooling facilities. In short only a sufficient supply of water should be carried, which, passing through a radiator of large surface, is cooled quickly and completely: all this increases the weight to be lifted, and augments the weight per horse-power of the motor employed.

How can this essential lightness of the motor be realised? Two different methods may be practised to secure this end. First there is weight-reduction by the selection of materials. To-day there are steels of marvellous strength, which allow cylinders to be manufactured with walls of insignificant thickness; for example, the barrels of our hunting rifles, which, with pyroxylised powders, resist enormous pressures and yet are not a millimetre thick at the muzzle. Hence, it is possible to have material both strong and light. A second means of obtaining weight-reduction is to dispense with all useless mechanism; from this point of view the "aviation motors" of the *Antoinette* make, those of M. Esnault-Pelterie, M. Renault, and even others, are absolutely remarkable. In particular, the design of the Esnault-Pelterie motor, having several cranks working upon the same shaft, and actuated by piston-rods disposed in a radial manner, has secured a considerable diminution in weight. A single cam ensures the working of the valves.

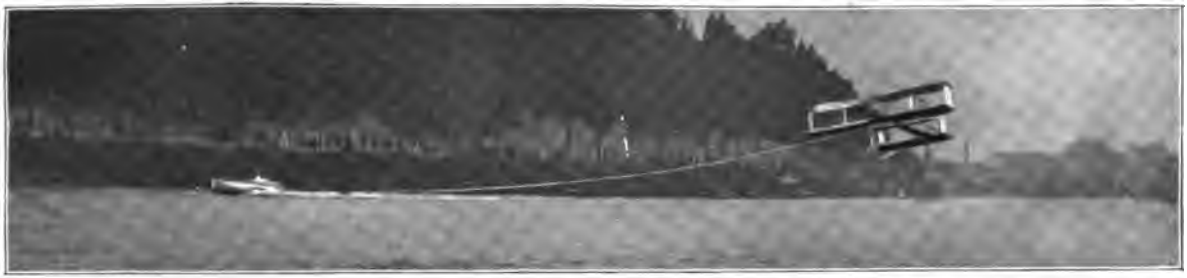
The "Gnome" rotary motor has achieved great fame in its latest applications, purely on account of the simplicity of its mechanism and the reliability of its running. Furthermore, an engine based upon a totally new principle, dispensing completely with cranks and connecting-rods, has been invented by Fodōr, a Hungarian engineer. The system is simple, strong, and reliable. It secures an appreciable reduction in weight, and also an increased compactness owing to the suppression of the articulated system. It is a decided step towards the "explosion turbine" which still remains to be evolved.

The latter will be invented; its realisation is essential to the future of aviation because the shocks, inevitable vibrations arising from the oscillating movement of pistons in motors working on the cycle principle, as are used in aeroplanes and dirigibles to-day, impose strains upon the frame, and appreciably fatigue the joints in the structure. Moreover, these vibrations are transmitted to the suspension and stretched steel wires, reducing their strength, and in the event of a combined effect might bring about even a rupture through the same cause which has produced so many accidents to suspension bridges.

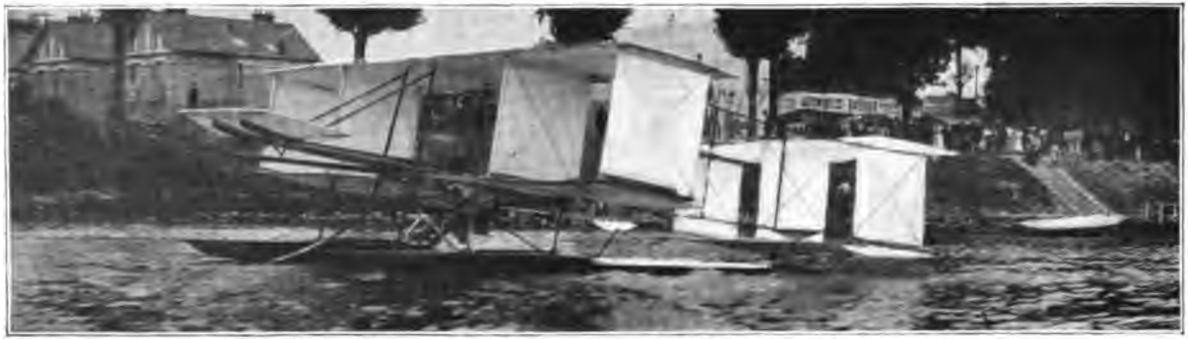
The rotary motor, of which the "turbine" is the ideal, has the advantage of eliminating all these shocks. Will it be possible to design this engine to work by the explosion of a gaseous mixture as it can operate with steam? It is impossible to say. But at any rate constructors must turn their attention henceforth to this question.

If lightness is the paramount condition which the motor must fulfil, it is imperative that strength and reliability in working be not sacrificed. With the successful realisation of this last condition, it will be possible—it will be advisable even—to reduce the weight of the motor more and more, as absolute safety will only be secured when it is possible to instal *two* motors on a given aeroplane, each developing sufficient power to sustain and to propel the apparatus. Then the "breakdown," the terrible motor failure, which inevitably brings about the descent, if not the fall, of the aviator, will be feared no longer. If one of the motors should fail, the other, already running, could be speeded up; and as each one would be

PLATE XXVII



Santos-Dumont's box-kite-like motorless aeroplane being drawn by the motor-boat "La Rapiere"

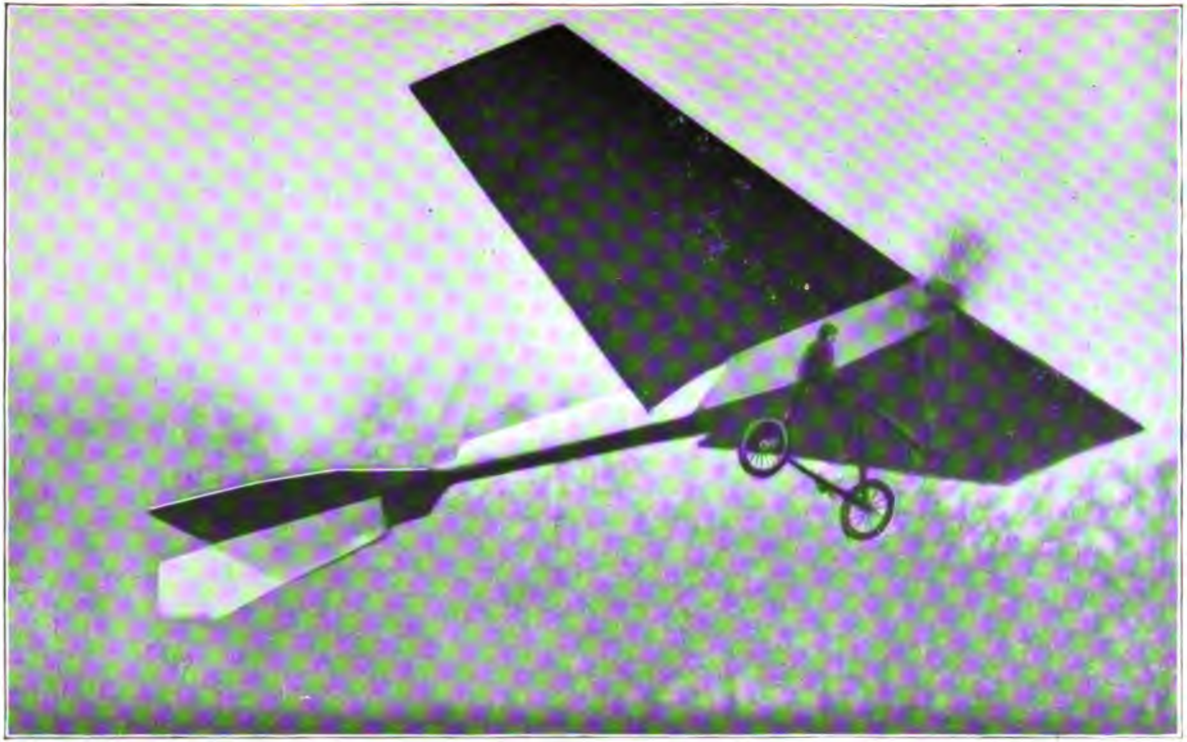


Launching from the water. Santos-Dumont's floating aeroplane.

Photos, Raffaële

THE FIRST ATTEMPTS IN AVIATION

PLATE XXVIII



"AN EARLY BIRD"; THE GASTAMBIDE-MANGIN MONOPLANE IN FULL FLIGHT designed to ensure sustentation, a fall would no longer be dreaded. The great progress that has been made in motors for some time past permits us to believe that this hope will become a reality at no distant date.

THE PROPELLER : SCREWS

The only propeller used in aviation (except with ornithopter apparatus) is the screw. We have explained its general properties in speaking of dirigible balloons; we have defined its "pitch," as well as the "slip," resulting from its working in the air.

But we must revert to the subject somewhat in speaking of its application to aviation apparatuses.

At present we are not very well supplied with really reliable data concerning aerial screws; the excellent works of Colonel Renard have elucidated the question without solving many individual points. Experiment *alone* can furnish data as to the practical value of a screw. But in such research operations it works "at a fixed point," that is to say, moves upon an immovable dynamometer, which gauges its mechanical effort. This data is not absolutely sufficient, as in aerial operation a screw does not furnish the same useful effect as when working at a fixed point. Yet such data is necessary, and therefore, above all, tractive experiments by means of a dynamometer with each screw must be made.

Once this result has been obtained, a serious question of vital importance will arise, since, according as to how it is settled in one direction or the other, there will result aviation apparatuses presenting features and qualities widely dissimilar. This question is: Should the screw be of small diameter, and revolve at high speed, or, on the contrary, should it be very large, and turn "slowly"?

These two ways of planning the propeller have given birth to "two screw-propeller schools." Both solutions have been tested. Large screws were the first to be used, especially on dirigibles, and in particular on those of Giffard, Dupuy de Lôme, and Renard. This condition, moreover, was compulsory at the onset, owing to the slow speed of the motors employed.

But when the explosion motor, with its very high speeds of revolution, entered aeronautical practice, preferences changed, and there was a rush on small screws turning very rapidly. There was a fear that the actual rotating speed of the motor would be "reduced," and it was desired to govern the screw directly by the engine by mounting it direct upon the shaft of the latter. Thus we see the Lebaudy dirigibles, the Voisin machines, the immense airship of Count Zeppelin, fitted with small screws running at a speed ranging from 1000 to 1500 revolutions per minute.

The appearance of the *Ville-de-Paris* and *Bayard-Clément* airships, fitted with large screws running at from 300 to 400 revolutions only, and especially the remarkable performances of the Wright aeroplane, the two screws of which rotated at a fairly low speed, served to support those who maintain very justly that the employment of large diameter screws is more advantageous. To-day there seems a more general tendency in the direction of screws of greater diameter and revolving less rapidly.

Another question, quite as important, is as to whether *one or two screws* should be used.

In principle, two screws, one running to the right, and the other to the left, thus revolving in opposite directions, are preferable in every way. In fact, with one screw only, the aeroplane tends to swing in the direction of its rotation, and its great surface alone prevents this deviation from becoming serious.

With screws of opposite pitch and direction, these two effects become neutralised, the one tending to bring the aeroplane to the right, and the other to the left. The motive effort is then quite symmetrical.

But the use of two screws may in certain instances present a great danger, and for the following reason. Let us suppose an aeroplane provided with two screws (Fig. 61 A) driven by identical motors, or by equal transmission of the energy from a single motor. Each has a turning effect following its axis, and as they are placed symmetrically with regard to the centre of the supporting surface, the resulting propelling effort is steadily applied at one point of the symmetrical plane of the whole contrivance. But if one of the two screws—the right, for instance—for some reason should cease to act (Fig. 61 B), either through a fracture or failure of the engine which drives it, the aeroplane is instantly subjected to the action of one propeller alone—the left one. This movement is eccentric. The apparatus is subjected to a propelling effort which in itself is eccentric, and it tends to assume an oblique direction. The machine assumes the position too quickly for the aviator to correct it in time by means of the rudders, and a fall may be the result. This was, unfortunately, what happened with one of the Wright aeroplanes. Orville Wright, having on board an officer of the American army, Lieutenant Selfridge, was a victim to this contingency. The aeroplane fell, the officer was killed, Orville Wright had an arm broken, and had to rest for two long months.

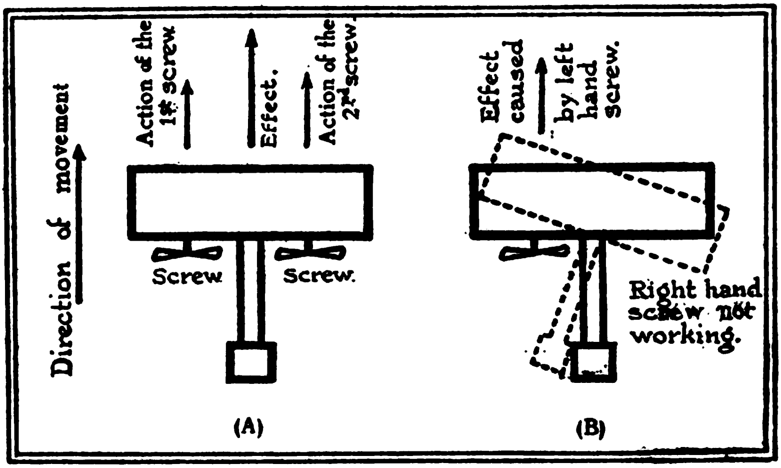


Fig. 61. Propulsion of an aeroplane by two screws

A, *with the two propellers*; B, *with one only*

From the point of view of safety, the use of a single screw is, therefore, much preferable. If it is absolutely desired to use two, it is essential that the disconnection or stoppage of one should arrest the motion of the other, and that by *automatic* means, as, for instance, the transmission of the power through a *single* chain. Under these circumstances, in the event of failure in propulsion the aeroplane would be in the plight of an ordinary "breakdown," and in its forced descent could make a "glide" through the air.

Lastly, one more doubt might arise in the mind of the constructor: should the screw or screws be placed at the bow or stern? In other words, should one have screws which "draw" or screws which "drive"? Opinions and practice are divided. In the French machines such as those of Blériot and Latham the single screw is at the prow. In the Farman aeroplane, it is at the stern of the carrying surfaces. The Wright Brothers have adopted this arrangement for their two screws, which are "driving propellers." All these aeroplanes have shown different qualities, but such as are incontestable. It is therefore impossible to declare off-hand in favour of one or the other, and the position of the screw will depend upon the wing-spread, the empennage, and more or less upon the long leverage of the latter.

THE "BODY" OF THE AEROPLANE

There is, also, one part of the aviation apparatus which we have neglected up to now, but which is nevertheless indispensable. This is the "body" which plays the part of the car of the dirigible, that is to say the space designed to carry the motor, the propeller, and the aviator, the "brains of the machine."

The "body" represents the serviceable part of the aeroplane, since it carries the travellers; but it has dimensions, and these cannot be avoided, however small the design may be. Therefore it will present to the air a resisting surface, which must be taken into consideration.

In the Wright Brothers' aeroplanes there is no "body." It is reduced to that of the aviator, sitting over empty space on a latticed seat, with the feet resting upon a cross-bar. This is an arrangement possible with operators as clever, as "artistic," as masters of their nerves, as Wilbur and Orville Wright, but in my opinion it is an arrangement to be condemned absolutely. Aviation is already a sufficiently daring form of aerial travel without increasing the risk, by decreasing the conditions of safety. Practical aeroplanes of real value, such as those of Blériot, Voisin, Farman, &c. . . . all have a "body" serving as accommodation for the aviator and the machinery.

This body, being compulsory, it is necessary to utilise it to the best advantage for the balance of the machine. First of all, we must give it, undoubtedly, the shape of the body of a bird or fish, with the large end to the front. Under these conditions, and if the framework is carefully covered with fabric tightly stretched and very smooth, its resistance to advance will be reduced to the minimum. This body, moreover, will serve a useful purpose; it will increase the lateral resistance, that is to say, oppose "drift" and the action of centrifugal force when turning.

Thus planned, the shape of an aeroplane becomes closely allied to that of a soaring bird. The action of the air upon the various parts of this "body," however, must be studied carefully as regards stability in the direction of travel, and here it is that Colonel Renard's work must be borne in mind. More than ever (as we have already said) the empennage is here indispensable to secure the safety of the apparatus.

AEROPLANES AND SPEED: AEROPLANES OF THE FUTURE

The real great advantage of aeroplanes in their application to aerial travel is *speed*. In all trials wherein somewhat prolonged flights have been accomplished, it has been seen that the present speed of aviation apparatuses is at least 60 to 70 kilometres per hour. In Farman's now historical journey from Rheims to Châlons on his French-built (Voisin) aeroplane, not only did the daring aviator achieve the first "aerial journey" worthy of the name, leaving a field of experiments to pass over villages and forests, but he even made it at a speed of 78 kilometres per hour. Again, recently, the speed of 105 kilometres an hour, exceptional it is true, was attained. No dirigible, at least at present, can equal such a performance, and the speed record in the matter of aerial navigation consequently belongs to the aeroplane.

Can this speed be increased?

Not only *can* it be increased, but it *must* be increased, if it is intended to make really practical use of aviation. At an important conference held at the French Society of Aerial Navigation in December 1908, the engineer, M. Soreau, a former pupil of the École Polytechnique, dealt with this question in his highly competent manner. He selected for his purpose a "family" of aeroplanes of the type constructed by the Voisin Brothers. Supposing all to be provided with motors giving the same weight per horse-power, propellers having the same output, and wings having the same co-efficient of efficiency he showed that the maximum *useful* weight would be obtained with an aeroplane having dimensions only 10 per cent. heavier than the existing aeroplane. But its speed must be *tripled*, that is to say must reach the figure of 180 to 200 *kilometres per hour*. Then the "useful" weight would reach one ton.

But, when our "artificial birds" shall have realised such speeds, when they can carry such weights, it will be possible no longer to be content with this construction of slender framework, a marvel of lightness, certainly, but lacking solidity. It will be necessary to make all its component parts very strong, to enable them to resist even the greatest strains to which they may be submitted. Let us cite here M. Soreau's important conclusions: "aeroplanes of large carrying capacity will have to be very stoutly built, not much larger than at present, at least for the next few years to come, but their speed will have to be double or treble that in vogue to-day. Now, for these new machines we shall be forced to employ other materials. It will be necessary in particular to attend to the reduction of their resistance to advance; in short it will not suffice to be content with constructing aeroplanes based strictly upon existing lines. These new apparatuses, so soon as they shall have been perfected and have received the sovereign sanction of experience, thus will become the first aeroplanes of a new family," and so on.

Hence aviation apparatuses will be perfected by "evolution," which is the case in nearly all the great developments realised in physical science or applied mechanics.

What must be remembered in these conclusions of one of the cleverest aero-mechanics of to-day is that before long, even very shortly, we shall see general speeds of 200 kilometres per hour. Truly then it will be possible to say that "distance no longer exists." Moreover, we may say that these high speeds *are* necessary. Painful accidents have occurred only too frequently owing to the aerial eddies overturning the apparatuses flying through the air. If the speed is very great, the power imparted to the machine, which increases as the square of the speed, will render it insensible to the slight fluctuations in the atmospheric currents, and it will pass through the eddies as the high-speed torpedo boats of to-day steam through the waves, or as the projectile whistles through the air, indifferent to the caprices of adverse currents.

WIND AND AEROPLANES

What we have said regarding the action of the wind upon dirigibles applies equally well to aviation apparatus; "Wind does not prevail for the aeroplane which moves in the *atmosphere*. It is as if this atmosphere were immovable. Wind only exists on account of the aviator changing position *in relation to the ground beneath*."

Consequently, we shall have to consider the same values in aviation as in aeronautics. If the independent speed of the aeroplane is less than that of the wind, it will be able to approach only the points of the space contained within a certain "approachable angle." If its independent speed equals that of the wind it will be able to approach any point to leeward of the line perpendicular to the direction of the wind at its point of departure. Lastly, if its independent speed is greater than that of the wind, it will be able to go anywhere. In all cases, its speed is governed by that of the wind in regard to resulting movement. In an extreme case when it flies with a dead following wind its travelling speed, with regard to a fixed guiding-mark taken on land, is equal to the sum of the speeds of the wind and of the aeroplane. It equals their difference if the aviator navigates against a "head wind." As to-day a speed of 78 kilometres per hour is possible, it is evident that, *at present*, an aeroplane can set out around Paris on an average 352 days out of 365; when a speed of 150 kilometres per hour is reached, it will be possible "to start out every day."

I insist most particularly upon this notion, as it is often distorted or acquired in an incorrect manner. For instance, if an aeroplane is travelling in an easterly direction in a south wind of 20 kilometres per hour at an independent speed of 60 kilometres per hour (Fig. 62) it will navigate *effectively* with a speed of 60 kilometres per hour; but the "section of atmosphere" in which it will have effected these 60 kilometres will be displaced 20 kilometres towards the north, owing to the effect of the southerly wind. Thus the aeroplane will have followed an oblique trajectory, represented by the diagonal of the parallelogram constructed with the help of two speeds—its own independent speed and that of the wind.

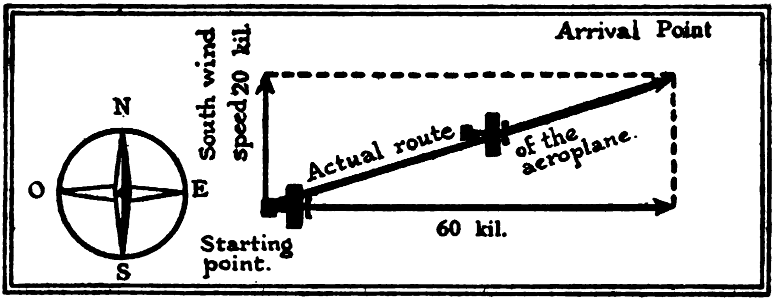


FIG. 62. Combined action of wind and propulsion speeds

Instead of following a straight line, the aeroplane will describe a diagonal route

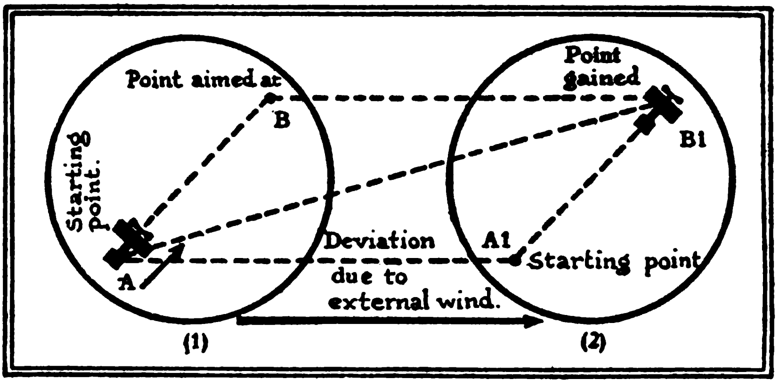


FIG. 63. Wind and the aeroplane: actual and relative routes respectively

The whole moves as if wind were non-existent, but as if the earth travelled beneath the aviator at a speed equal, but contrary, to that of the wind

This conception may be "materialised" even, so to speak, in the following manner. Let us imagine an enormous aerostat, formed of a perfectly impermeable envelope, and maintaining its equilibrium high in the air (Fig. 63). We will suppose that this balloon has dimensions sufficiently large for an aeroplane to be able to describe evolutions in its interior atmosphere. This atmosphere will be sheltered completely from the action of the outer wind, since it is enclosed in an air-proof envelope; the aeroplane will therefore manœuvre in still air, and will go from A to B, but during the time it will take to accomplish this journey, the whole balloon will have been transported by the outer wind from (1) to (2). Certainly the aeroplane will arrive duly at point B, but this point B will have been transported without the aviator being aware of the fact to B^1; so that he will have no longer below him the part of the terrestrial surface which was below point B, but really that which is below point B^1. Now let us imagine the envelope which isolated the interior atmosphere of the aerostat to be removed; nothing is changed in the general conditions, but we can thus understand the true road, AB^1, of the aeroplane.

HEIGHT AT WHICH IT IS ADVISABLE TO FLY: SAFETY

The height to which it is advisable to rise to practise aviation is connected intimately with the conditions of safety laid down by the aviator.

At first sight it may be imagined that it is essential to decrease the risks of accident by navigating very closely to the ground; to sweep closely to the earth like swallows because, it may be thought that "if one fall, one will fall from a lesser height."

This reasoning is admissible for risks entirely "experimental"; when one is not quite sure of the stability of the apparatus in which one is to ascend. But once this apparatus has been tested, and once the efficiency of its equilibrium has been ascertained, then it is necessary to avoid too close a proximity to the ground, and to navigate at a certain height, say, at about 100 metres.

As a matter of fact, let us consider what takes place in the immediate neighbourhood of the ground (Fig. 64). The moving molecules of the air, the horizontal displacement of which constitutes the wind, are forced, when brought into immediate contact with the terrestrial surface, to follow all its superficial variations and to become deflected by its projections. The gaseous molecules thus follow, approximately, the undulations of the ground, in at one time an ascending, and at another moment a descending path, and if their speed is of little consequence, that is to say, if the prevailing wind is not very intense, these inflections of the currents of air cause "ascending winds" and "descending winds," as is illustrated in Fig. 64.

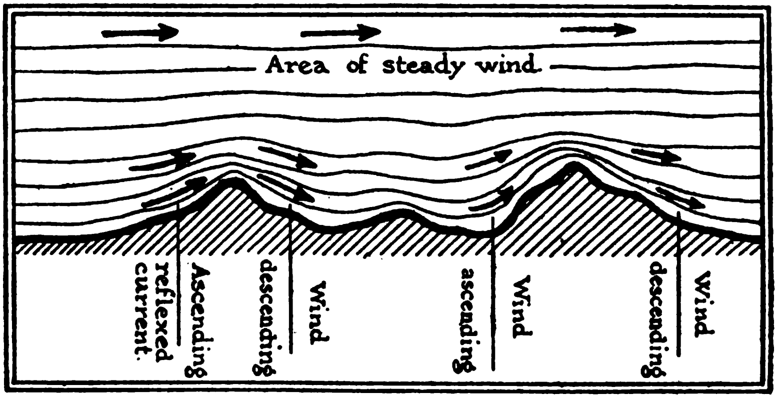


FIG. 64. Effect of inequalities of the ground surface upon the movement of the air

The horizontal currents are deflected by the irregularities of the ground, which set up vertical currents

Now the aeroplane is so designed that the currents of air are met horizontally by its wings, and not so as to be struck in an oblique manner. These vertical winds therefore will be capable of "twisting" the aeroplane round, and so placing it that in its fall it will no longer meet the air by its extended surface, but with its side. This will bring about a sudden descent, in other words, certain death to the aviator.

These atmospherical fluctuations disappear in proportion as one rises into the air, and at a certain height, as is shown in our sketch, the strata of air becomes steady and flows in a horizontal manner, being quickened solely by those "undulatory movements" so ingeniously described by M. Soreau. It will be only at these altitudes that the aviator will be sure to find the normal laws of the atmosphere; it will be at these heights that he will have to fly if he will desire his aeroplane always to be "under the best conditions" for which its various elements will have been calculated. Lastly, it will be from where, in the event of a breakdown to his motor, he will be able to make the "glide" through the air, which, with a soaring flight, will carry him safely to the ground; whereas he will not be able to effect such if he be caught in a current of ascending air which will capsize his aeroplane and infallibly precipitate a fall. This descending glide will be effected with the greater safety inasmuch as it will commence higher above the ground, and also because the aviator will be able better to select his landing-point.

In the early days of aviation, it was often asked if the highest altitudes would not be impossible to the aeroplane; if the greatly rarefied oxygen would be insufficient to bring about the combustion of the gaseous mixture, the explosion of which supplies the requisite energy; and whether the *carrying surface* could be supported owing to resistance from a thinner atmosphere. Would these conditions be sufficient to assure the sustentation of an aeroplane which would possess sufficient stability no longer? In the case of average altitudes (between 100 and 1000 metres) easily accessible to the aeroplane such objections do not exist. At a height of 100 metres, the supporting power of an aeroplane's wings is not reduced, owing to the density of the air being diminished by no more than $\frac{1}{80}$ of its value at ground level. In regard to the highest altitudes, demonstration has dispelled triumphantly apprehensions on this point, for aviators have already reached extreme altitudes. The French aviator Paulhan, at Los Angeles, U.S.A., in 1910, rose to a height of 1260 metres; Latham, on July 7, 1910, mounted to 1384 metres; on July 30 Oliesloegers notched 1524 metres; and a Belgian aviator, Tyck, on August 1, 1910, gained a height of 1700 metres. But the two record-breakers in height are Morane, with 2521 metres and Chavez with 2646 metres! On September 20, 1910, the last-named succeeded in crossing the Alps, from Brigue to Domodossola, over the crest of the Simplon.

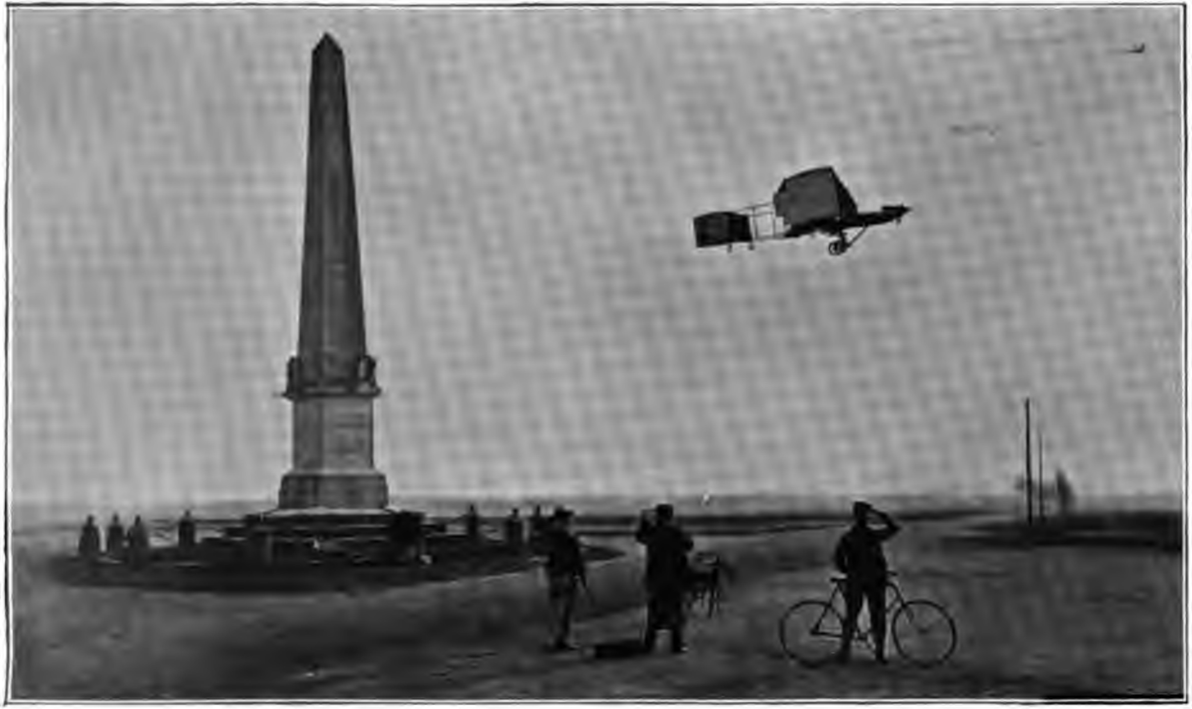
The question of safety is connected closely with that of landing, and the latter is, as may be easily understood, of the greatest importance to the aviator undertaking an aerial journey. "It is not all skittles, I must get out of this," said La Fontaine's fox. It is not only flying: one must regain the ground, and return thereto without breaking one's bones.

Now, calculation, and calculation based upon experimental data, shows that for a given aeroplane, there is a minimum motive power necessary to obtain the "governing speed." So soon as a motive power exceeding the minimum is brought into play, two results and, consequently, two speeds are possible. Thus, if we have a motor the power of which exceeds the mimimum speed by 4 per cent., the two speeds will in one case be 18-100ths in excess, and in the other 17-100ths less than the governing speed, according to the inclination of the wings. If the motive power exceeds the minimum power by 15 per cent., the two possible speeds are, the one a third in excess of the necessary speed, the other one-quarter less, according as to whether the wings are inclined more or less by the action of the elevator.

Thus, since it is possible, by means of a slight excess of power, to have two speeds at disposal, it will be possible, as M. Soreau remarks, to use the greater for the "travelling speed" of the aeroplane, and the lesser one for landing, which thus will be effected without danger, for when the apparatus has approached closely to the ground, the fall caused by the excessive inclination of the wings will be deadened appreciably by the "mattress of air" interposed between the ground and the supporting surfaces. It is when alighting that the mechanical absorbers, upon which the wheels of the launching carriage are mounted, become indispensable. Undoubtedly, the landing of heavy aeroplanes will require elaborate precautions, and will demand extreme cleverness and presence of mind on the part of the aerial pilot.

How do accidents happen? From two different causes—the sudden stoppage of the motor, or the breakage of one of the essential elements of the aeroplane. This last possibility scarcely can be admitted, since, if the aeroplane has been well designed and carefully constructed with first-class materials, the strength of which has been thoroughly determined; if, moreover, all parts of the apparatus have been examined

PLATE XXIX

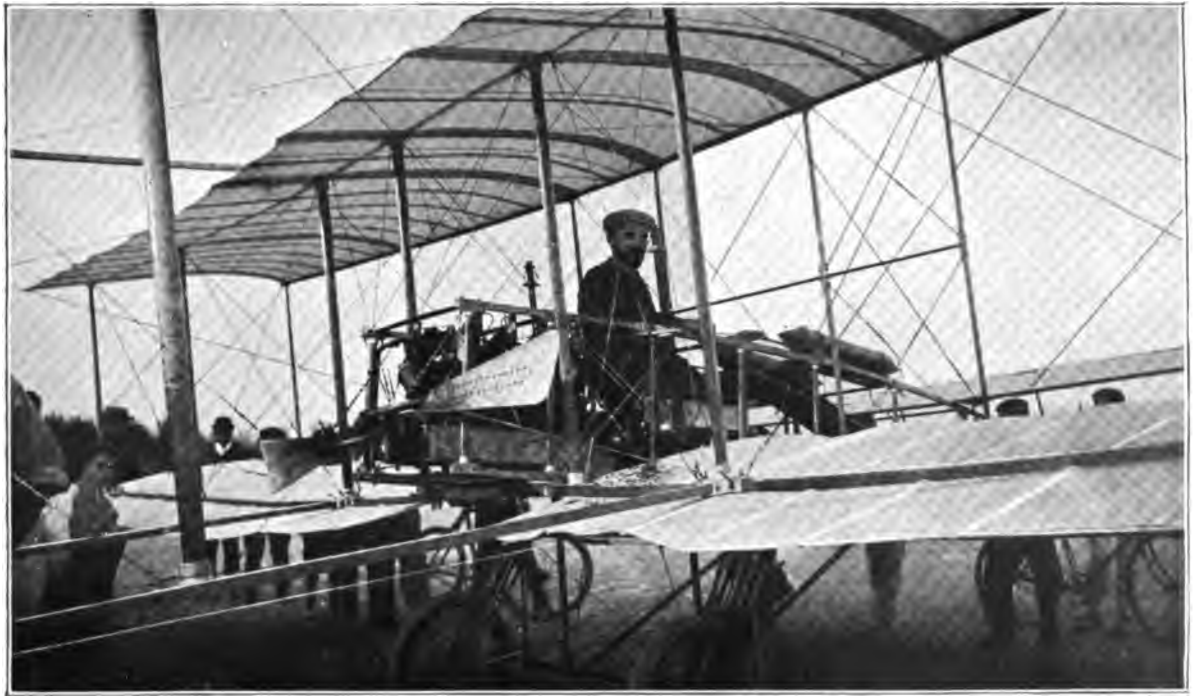


Photo, Neurdein

HENRY FARMAN'S FLIGHT FROM CHALONS TO RHEIMS

Boxed type of aeroplane

PLATE XXX



Photo, Raffaële

HENRY FARMAN AT THE WHEEL OF HIS FIRST AEROPLANE

The front of the aeroplane is to the right carefully before each ascent, and the mounting, connection, and assemblage have been inspected in detail, when built, the unexpected breakage of any essential part *should not* develop. But, you will say, there are the road accidents? No, not in aviation; for on the "highway of the air" there are neither shocks, bumpings, nor collisions to be feared, at least not at present; this road is wider than those which traverse the earth in all directions, and there is not only more room to pass one another horizontally, but it is also possible to keep clear of other machines "above or below." Moreover, our aerial roads are not overcrowded, at present. Again, the governing speeds not varying very much, the movements of the different controlling mechanisms are not subjected to appreciable fluctuation.

There remains motor failure; but we have pointed out, in speaking about explosion engines used in aviation, that their continuous development will bring about the desired reduction in weight. Very soon, therefore, we shall have motors at our disposal, the weight of which will be reduced sufficiently for it to be possible to carry two engines weighing no more than, and each of the power of, the single existing motor; that is to say, either will be sufficient to sustain and to propel the aeroplane. Under these conditions, together with a device automatically setting the second motor in motion in the event of sudden stoppage of the first, engine failure will be feared no longer.

In any case, should this occur, it would be dangerous only over towns, where descent would be hazardous, if not fraught with danger, or above forests, owing to the trees, which would injure passengers possibly and prove disastrous to the wings. There, is, however, one part of "the terrestrial globe" which offers danger—descent on *water*. Undoubtedly, the large surface of the wings can prevent the apparatus foundering immediately, but the aviator, pinned under the planes and "entangled" in the wings, might not be able to disengage himself without difficulty. It will be advisable to provide aeroplanes, intended for long journeys, with special safety contrivances, in view of a descent upon water.

"Accidents" will happen. Undoubtedly, daring pioneers in the air will forfeit their lives in the desire to score another victory over the forces of Nature. But have not all the conquests of human genius—navigation, railways, the motor-car, even current industry—been effected at the cost of heavy sacrifices! And are not the "accidents" of daily life as formidable as those to be feared in the new method of locomotion, which will be attended, however, with less serious results, because, reputably more dangerous, it will be practised with greater care?

OTHER FORMS OF AVIATION: HELICOPTERS AND ORNITHOPTERS

At the commencement of this study of aviation, we said there were three types of apparatus "heavier than air." We have investigated in detail those which have given the most practical results so far—aeroplanes. It now remains for us to speak about the other two.

The first is *helicopters*, that is to say, apparatuses which hold themselves in the air, not through the vertical component of air thrust upon a moving surface, like kites, but by the direct sustaining effort of a screw, having horizontal blades, revolving about a vertical axis, and driven by the motor.

It was the helicopter which first haunted the brains of aviators. As far back as 1852 Ponton d'Amécourt and de la Landelle, buoyed up by the enthusiasm of Nadar, the celebrated photographer, by Press campaigns, conferences, &c., maintained that the future of the "heavier than air" machine would be by means of the screw—the "sacred screw," as it was called by Ponton d'Amécourt. Their scientific support was Babinet, a member of the Academy of Sciences, and he it was who evolved the name "helicopter" to baptize the apparatus which he thought would realise the absolute conquest of the air.

What gave weight to the assertions of these tireless apostles was the popular success of flying toys, real miniature helicopters. These ascend with the greatest ease, either through the effort of twisted india-rubber, or from impetus imparted by uncoiling a string, and appear to defy gravity and to point to the "highway of the air."

Intellects were fired; controversies became furious; a study was made of the manner in which the screws should be arranged. To avoid the rotary movement which a single screw imparted to the body of the apparatus, a vertical "resisting plane" had been introduced into certain types of this toy, which opposed itself to the rotation of the whole. The danger of this plane was soon grasped, as, remaining nearly vertical, it offered too considerable a purchase to the wind. The fundamental point in the construction of helicopters was recognised, therefore, to be the simultaneous use of two screws turning in opposite directions about vertical axes. In this manner the effects of torsion, due to each of the two propellers, were equal and contrary. In other words, they destroyed one another, whilst their lifting efforts were combined. An automotor helicopter was constructed on this principle by Dr. Hureau de Villeneuve. There was a small steam-engine, driving two inverse screws revolving in opposite directions about the same vertical axis. All helicopters realised or planned hitherto comprised the use of an *even* number of screws of contrary pitch, revolving in opposite directions to one another.

Experiments were made with helicopters, but with little success. Why, is known to-day. The motors used were too heavy, and the intimate scientific discussion of the problem by mathematicians discouraged investigators from embarking on these lines for a long while. Then Colonel Renard tackled the question, which, as usual, he elucidated in his works on *sustaining screws.*

In a communication which he made to the Academy of Sciences at the end of the year 1903, Colonel Renard gave the results of his long researches, carried out at Chalais-Meudon, with screws employed for lifting a certain weight directly from the ground—that is to say, with "sustaining screws." He had demonstrated already that aerial navigation by aeroplanes would be possible when the weight of the motor was reduced to 5 kilos per horse-power. Devoting his remarks to the helicopter, the learned Colonel showed that the maximum weight which the screws of this apparatus would be able to lift would increase inversely to the sixth power of the weight per horse-power of the motor employed. This result strongly encouraged helicopter inventors, but we must reckon not with theoretical "limit" loads, which it would be impossible to exceed, but with the real loads compatible with the resistance itself of the screws. Under these conditions a really transportable load limit is obtained quickly, and these loads are lighter for the helicopter than the aeroplane. Hence the enthusiasm manifested in this apparatus is distinctly explicable.

In 1904, Colonel Renard even suggested sustaining screws of 2·50 metres diameter, of perfect resistance, and not liable to distortion under the effect of thrust, although their total weight was very small. He obtained this result by introducing a universal joint which permitted the screw-shaft to assume the resultant direction of the various efforts bearing simultaneously upon it.

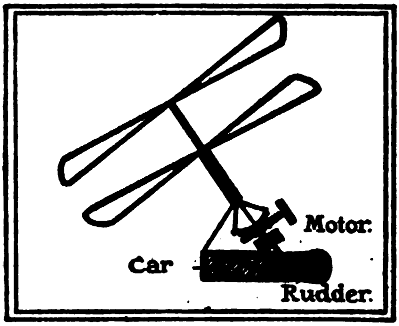


FIG. 65. Principle of the Léger helicopter

Two screws of concentric axes revolve in opposite directions, and their common axis may be inclined for horizontal propulsion

Amongst the various dispositions proposed for helicopters, there is one conceived and constructed by Engineer Léger, under the auspices of H.S.H. Prince Albert of Monaco. Its principle is shown in Fig. 26. The two screws of contrary pitch, turning in opposite directions, are mounted upon two concentric axes. Each axis being vertical, lifts the car; but, if the axis is inclined, as shown in the figure, an oblique movement through the atmosphere must result. The apparatus has been tested at Monaco, and the vertical elevation of an experimenter has been effected.

A composite solution, of which Colonel Renard himself had thought, has been proposed. It is an apparatus which would be a *helicopter* for lifting itself from the ground, and would become an aeroplane once in the air. Such a solution, if it were ever practicable, would solve an acute problem, since the great disadvantage of aeroplanes is the necessary "launching" space. So long as there is level ground, or even broad roads, ascent is quite a simple task. But in wooded or mountainous country an aeroplane having landed, cannot re-start, whereas if it had a screw and vertical axis, which would lift it perpendicularly, departure would be easy, and once raised into the air, the apparatus would have the advantages of an aeroplane. It is to be hoped that serious investigations will be made in this direction; success will constitute a great development, and perhaps even the future of aviation. The "gyroplane," which we describe later, is a decided step in this direction.

Ornithopters, those apparatuses with "flapping" wings, seeking to imitate exactly the process of lifting and sustentation which characterises the flight of birds, have been tested less than helicopters. The difficulties of construction are so much greater, and the vibrations and shocks to which their framework is subjected cannot fail to tell on the joints. Despite these difficulties, a Belgian aviating engineer, M. Adhémar de la Hault, has devised an *ornithopter*, which we illustrate. In the latest experiments, this apparatus was able to rise slightly and to leave the ground for a moment, but an accident to one of its parts interrupted the trials, which are to be resumed later.

COMPOSITE SOLUTION : SOARING BALLOONS : CAPAZZA'S LENTICULAR

There remains another composite solution for us to mention. This does not consist of a combination of two systems of aviation, but a balloon and a soaring arrangement. It is an attempt recalling those sailing-vessels known as "auxiliary-engined" craft, often used in trade and pleasure navigation.

Its inventor, M. Capazza, a French aeronaut with the finest "aerial" career (he was, in fact, the first aeronaut to cross the Mediterranean from Marseilles to Corsica, and in a balloon, which has not yet been repeated), designed an immense aeroplane, but with its sustaining plane *lighter than air*. He uses a balloon, not of the ordinary spherical or pisciform shape, but having the flat form of a lentil. This lentil, however, is not symmetrical, as regards its centre; it is not a "surface of revolution." Its greater thickness is brought to the bow, so that, cut in the direction of its axis, its section is that of a fish (Fig. 68). A longitudinal empennage forms, above and under this envelope, a kind of aileron, a "keel" which contributes to stability, which is increased still more by an horizontal empennage at the stern. The whole of the stern of this lentil, thinned to its back edge, in reality constitutes a marvellous natural empennage.

The total capacity of this envelope is 15,000 cubic metres, and it is reinforced internally by metallic circles. These support a car in which are three motors of 120 horse-power each, driving three screw-propellers. The weight of the car is carried below the greatest thickness of the balloon, *i.e.*, well forward of the centre, as shown in the diagram. The interior metallic hoops distribute the load over the whole surface of the envelope.

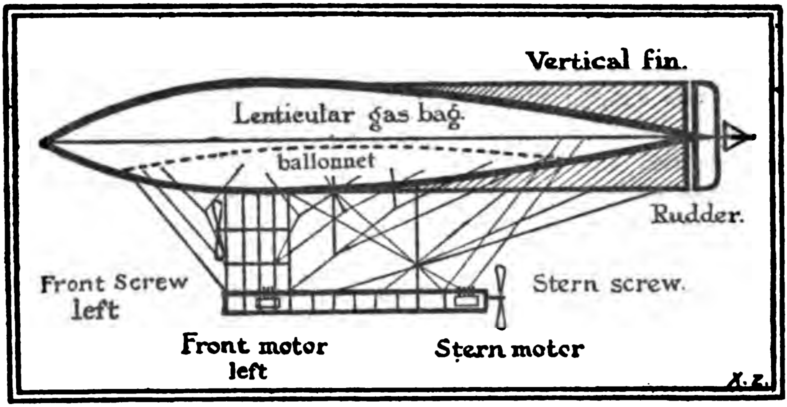


FIG. 66. Side elevation of the Capazza lenticular balloon

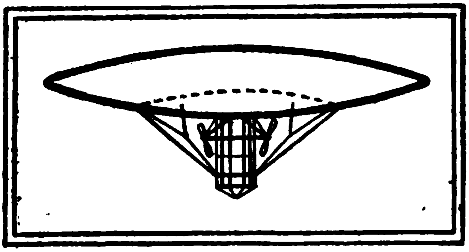


FIG. 67. Front view of the lenticular balloon

At first sight the apparatus works like a dirigible: but, on account of the flat and non-symmetrical shape of the envelope, it possesses additional properties. Let us imagine a movement of ascent or descent being imparted to it. The apparatus will become inclined immediately, as the two areas, that of the bow and that of the stern, will be pressed unequally by the air; the back area offers a greater resistance to ascent or descent than the front. If, for instance, the movement is ascending, the stern will be depressed, the bow will rise up, and the vertical ascensional movement will be transformed into an oblique displacing movement towards the bow. The screws will add their propelling action to what is thus obtained, and will help, according to the expression of artillerymen, to "flatten the trajectory." The direction of the balloon will become the more horizonal as its independent speed will be increased.

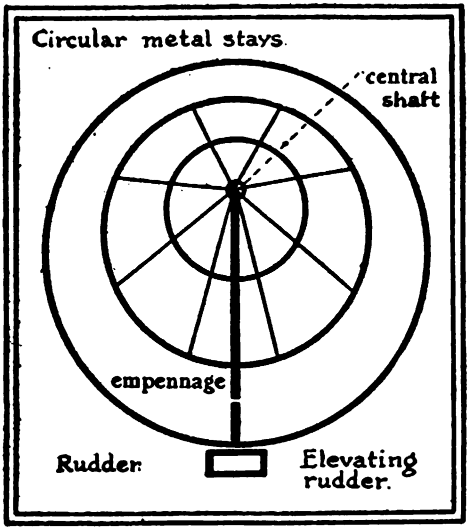


FIG. 68. Plan of Capazza's lenticular balloon

Now let us suppose that at a given moment the *total* weight of the apparatus, envelope, car, motors, passengers, and cargo, for some reason or another, exceeds the weight of air displaced, say either because the lenticular balloon in rising has gone beyond its zone of equilibrium on account of its acquired speed, or because physically the inner gas has contracted, and which the ballonnet will have replaced with air: the balloon will tend to descend immediately, but an inverse phenomenon will occur. The greater surface of the stern will lift, and the balloon will become inclined; it will descend, but in gliding in an oblique manner upon the molecules of air in the manner of an aeroplane, will utilise this descending movement to progress horizontally. This effect will be added to the speed imparted by the screws, the propelling force of which will thus be increased by successive ascents and descents.

Such is this ingenious, curious apparatus, which is so original in its conception, and which it would have been impossible to let pass without saying a few words. It would be very interesting to see it realised, for, apart from the services which it would render as an airship, it might become a veritable experimental laboratory for everything concerning aviation.

CHAPTER IV

DESCRIPTION OF SOME AEROPLANES

I. BIPLANES

FRENCH AND AMERICAN DESIGN : THE VOISIN AND WRIGHT AEROPLANES : COMPARISON OF THEIR EFFICIENCIES AND DISADVANTAGES

THE VOISIN AEROPLANES

WE will now proceed to describe, somewhat more in detail, the various types of aeroplanes; at all events, those which have accomplished brilliant flights, and consequently have demonstrated their efficiency. And it is necessary, in all fairness, to begin with the excellent aeroplanes, swift and sure, built by the Voisin Brothers, the eminent French constructors. Their name, as a matter of fact, is inseparable from those of the daring spirits, who, in France, opened the highway through the air by their magnificent achievements: I mean Messrs. Henri Farman, Delagrange, Rougier, &c. The details given in the preceding chapters will enable the reader to appreciate and to compare better the different machines which we will now describe in turn.

We will mention first the original Voisin machines. These apparatuses, in a way, are historical, as they were the first aviation appliances in Europe. The present craft do not differ from their "prototypes" except in modifications of detail, and reference to the illustrations will help to reveal these divergences.

The Voisin aeroplanes of the original type belong to the "cellular" *biplane* class. Between the two parallel supporting surfaces which constitute the wings or planes are vertical walls, formed of fabric stretched over the cross members, designed to oppose lateral deviation and to maintain automatically the equilibrium of the aeroplane when turning. The general arrangement of this system is shown in Fig. 30. In the recent Voisin biplanes the builders have suppressed the vertical walls.

The design combines strength and lightness. The wings are of india-rubber sheathing stretched upon a diagonally braced ashwood frame. The spread of the wings is 10·20 metres; depth 2 metres; and of the "stays," which vertically maintain the distance between the two supporting surfaces, 1·50 metres. These surfaces are slightly curved, the concave face being presented towards the earth. When the apparatus is in flight, the "chord" of the arc formed by the profile of the wings makes an angle varying from 6 to 8 degrees with the horizontal. The surface of this plane is about 40 square metres.

The whole of the supporting surfaces, called the "central cell," has a balancing apparatus or "empennage," formed of a "rear box" which also follows the form of a biplane, of less spread than the central cell—3 metres long only, by the same depth of 2 metres, spaced 1·50 metres apart, and curved like those of the principal planes. This rear cell or "tail" is placed 4 metres behind the central cell, and between its two surfaces is placed a plane moving about a vertical axis which constitutes the *rudder*. The superficies of this rear cell is thus 12 square metres, which brings the total area of the planes to 52 square metres. The "body" of the aeroplane is a wooden framework with cut-water or wedge-shaped ends covered with carefully stretched canvas. Its greatest width is 75 centimetres; length 4 metres. The aviator's seat is so placed that when he is seated the centre of gravity is at a point which extends vertically 25 centimetres from the front edge of the supporting surface (edge of attack); in front of the seat are placed the wheel and the pedals controlling the rudders.

This body carries the elevator composed of two surfaces projecting on either side of the prow and moving upon a common horizontal axis. The shape is plane-convex, the plane being turned always towards the earth, and the convex side to the sky.

The engine is an eight-cylinder "Antoinette" motor developing 40–50 horse-power; it has eight cylinders, and weighs 80 kilogrammes. It is so mounted upon the body that its centre of gravity is a trifle forward of the rear edge of the carrying surfaces.

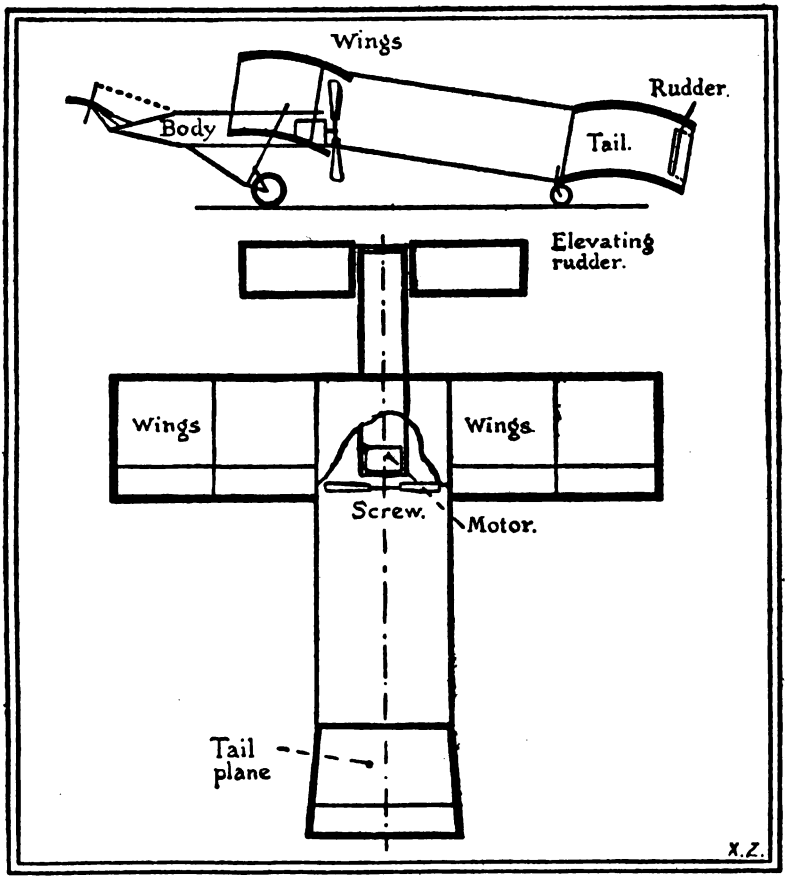


FIG. 69. The Voisin aeroplane (Delagrange type)

The screw-propeller has two blades; it is placed astern of the central cell. It is built up mainly of steel tubes covered with sheet aluminium. Its diameter is 2 metres; it is coupled direct, without any reducing gear, upon the motor shaft, and runs at a speed of 1050 revolutions per minute.

The whole is carried upon a wheeled carriage built of tubular steel having four pneumatic-tyred bicycle wheels.

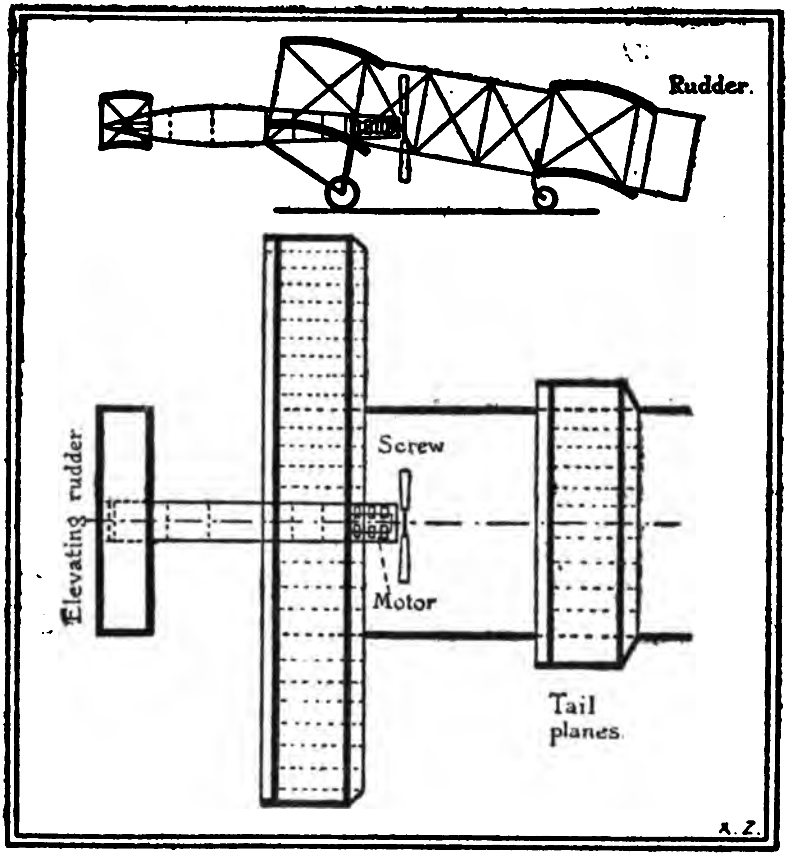
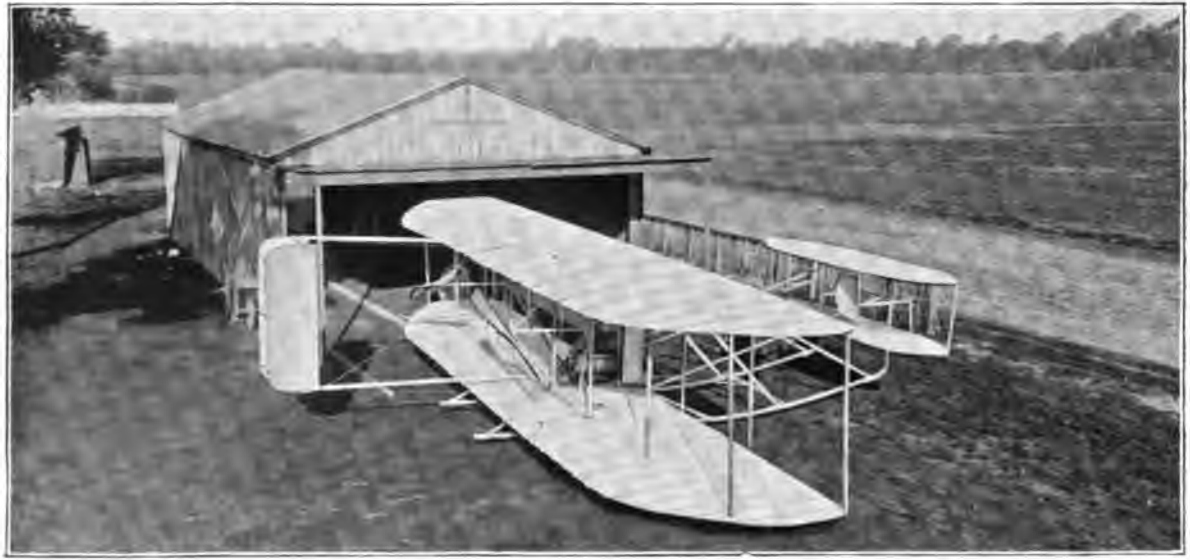


Fig. 70. The Voisin aeroplane (H. Farman's type)

Those in front which directly support the central cell and motor are of 50 centimetres diameter; the rear are of 30 centimetres diameter. The total weight of the apparatus together with the aviator is 530 kilogrammes.

Such is the simple and solid aeroplane with which Henri Farman demonstrated the prowess of which we spoke in relating the history of aviation. This aeroplane has undergone some modifications; its pilot fitted at the front a third surface above the first two, thus converting it into a

PLATE XXXI

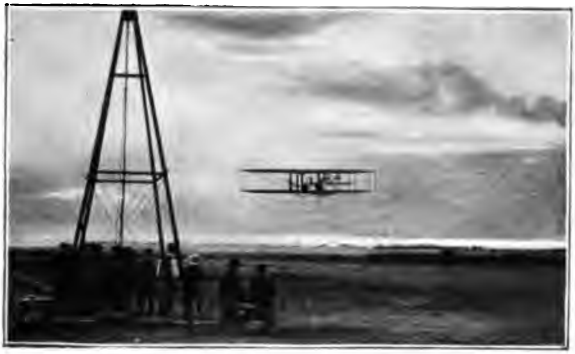


THE WRIGHT AEROPLANE EMERGING FROM ITS SHED AT AUVOURS CAMP

Prow to the right

Photo, Branger

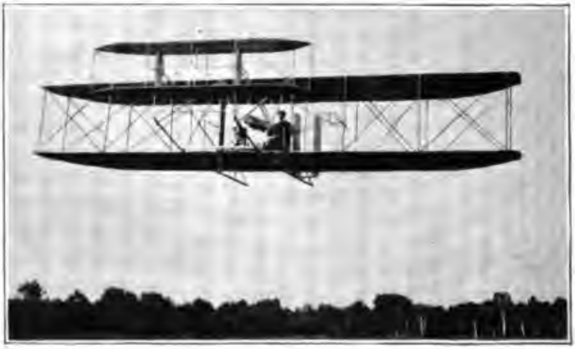
PLATE XXXII

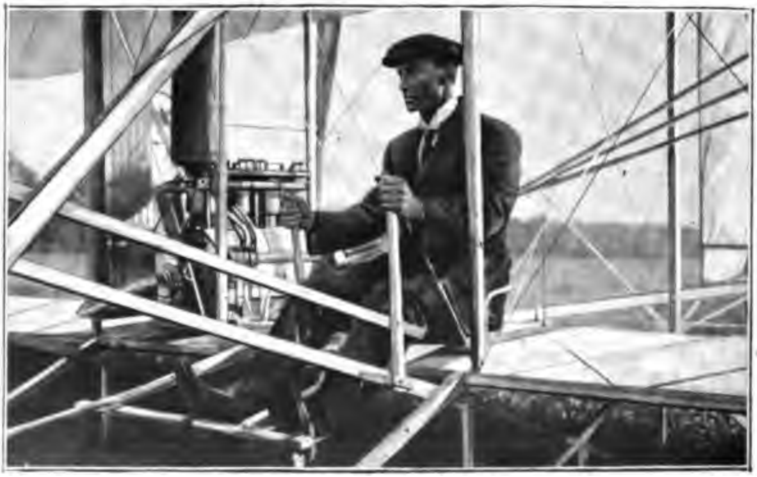


THE WRIGHT AEROPLANE AT THE MOMENT OF LAUNCHING BY THE FALL OF A WEIGHT IN THE DERRICK

THE WRIGHT AEROPLANE IN FULL FLIGHT

Photos, Branger





WILBUR WRIGHT AT THE WHEEL OF HIS AEROPLANE
SHOWING THE TWO CONTROL LEVERS

"triplane"; but the enthusiastic aviator seems to have renounced this adjunct, and to have reverted apparently to his original biplane. This machine attained a speed of 79 kilometres per hour in the journey from Châlons to Rheims, covered at an average height of 40 metres (27 kilometres in 20 minutes).

The Voisin aeroplane steered by Delagrange in his early flights (Fig. 70) vividly recalls the Farman aeroplane in its broad lines, which is not surprising, seeing that it came from the workshops of the same constructor. The only difference is a space of 3 metres between the central cell and the rear balancing cell.

Having given the details of the Henri Farman aeroplane, the diagram explains itself sufficiently; otherwise further details of the Delagrange aeroplane may have been necessary. Its total surface is 60 square metres, and it has attained, with a 50-horse-power Antoinette motor, and a screw of 2·10 metres, a speed of 70 kilometres per hour. Its total weight is 450 kilogrammes. Since the first flights of H. Farman and Delagrange, accomplished in 1908, and which already appear so long ago—the advance has been so great as to be a huge stride—the Voisin Brothers no longer trouble about their achievements and victories. Their machines represent one of the most stable and most reliable "heavier than air" apparatuses in aerial navigation. We will refer to their latest triumphs later on.

THE WRIGHT BROTHERS' AEROPLANE

We have shown a remarkable aero-biplane of French construction which fulfils automatic stability, be it longitudinal or lateral. Let us now give, in some detail, a description of the famous aeroplane which created widespread enthusiasm during the summer of 1908, and the prowess with which (we are apt to forget, perhaps a little too quickly, this attribute of the French aviators) would seem to show decidedly the "path through the air." In short, we will compare the American aeroplane with those which we have already described.

The machine, evolved by the brothers Wilbur and Orville Wright, in its earliest form is, like the Voisin aeroplanes, a biplane, with an elevator in front and a rudder at the stern.

Its main feature is the absence of a fixed balancer. The "foundation," that is to say the total length of the system longitudinally, is 9 metres. The two surfaces of the biplane have a spread of 12·50 metres each, by 2 metres breadth. The fabric of which they are made is stretched to the utmost upon two wooden frames formed of two longitudinal members strengthened by a series of transverse pieces. Each of the latter is doubled, and formed of two incurved laths, which are kept taut by wedges at the stern. This latter, very fine, very thin, extends to the rear part of the wings a certain elasticity, a sufficient suppleness, to facilitate the "warping," by which means the celebrated American aviator secures the lateral stability of his aerial vehicle. Steel wires stretched diagonally assure the indeformability of the wings. The fabric is riveted to the front edge of the plane members; at the back, to secure the finest possible finish, the edges are sewn together. The two planes are 1·80 metres (6 feet) apart, and this spacing is secured by vertical bracings, some of which are rigid and others articulated. Those of the centre, by means of diagonal supports, constitute indeformable parallelopipeds, in such a way that those of the extremities, fixed to the wings by screw rings, are able, through the articulation, to submit to warping which will deform the extremity slightly.

The planes rest upon two skids which form a kind of sleigh, because—it may be necessary to point out at once—the apparatus of the Brothers Wright is not *self-starting:* there is no wheeled carriage to give it the impetus to rise.

Launching is artificial, and requires an extraneous force. The skates constitute the part of the apparatus which is brought into contact with the earth in landing. Furthermore, they are curved, like those of sleighs which travel over ice.

The skids form also the "foundation" of the aeroplane. At the front they carry the elevator, and at the stern the rudder. The Brothers Wright have adopted an elevator very similar to that laid out by Colonel Renard, which he used for the first time on *La France* in 1885. They have set it in such a manner that its concavity may be varied as desired by the pilot in synchrony with the movements which he may have to give to the aero-

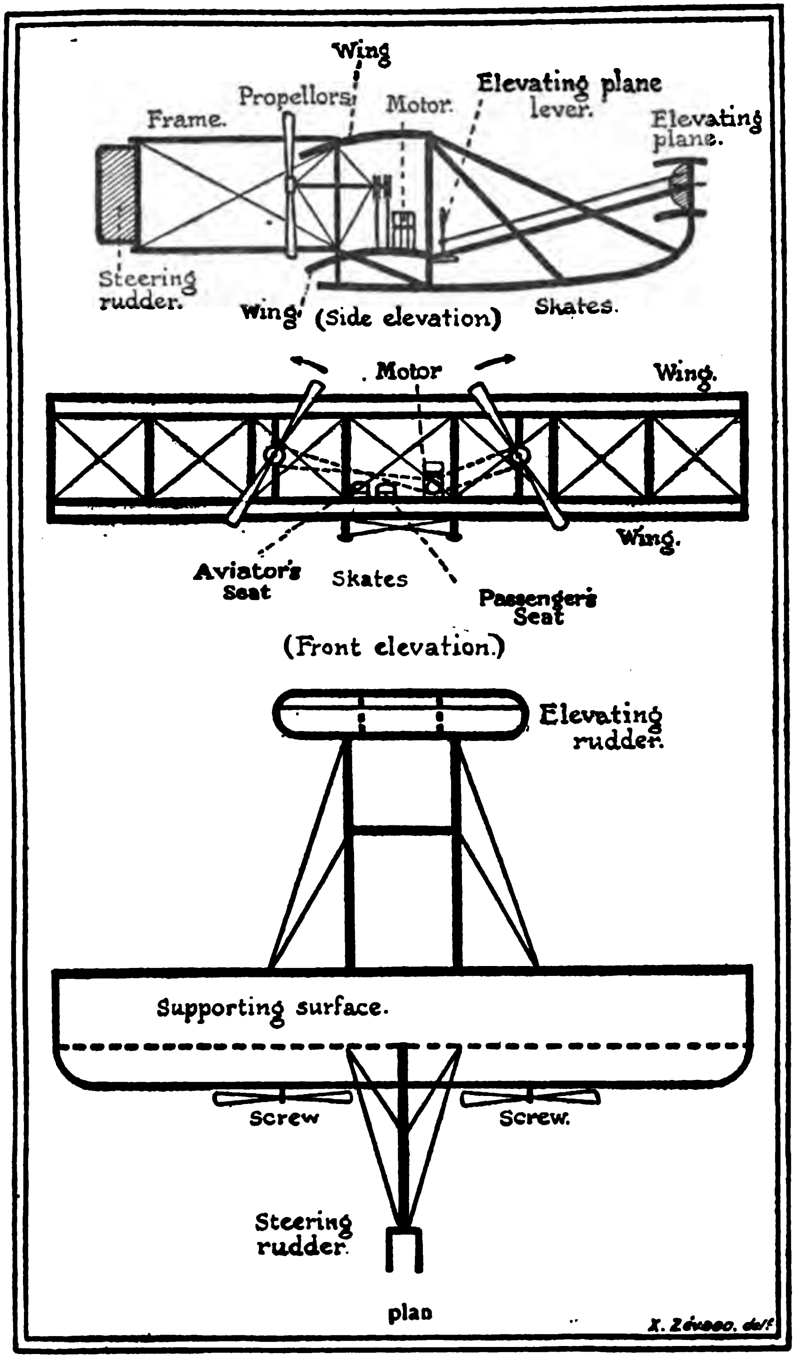


FIG. 71. The Wright Brothers' aeroplane

plane. The inclination of this rudder is controlled by a lever which the pilot holds in his left hand.

The rudder, comprising two vertical planes, is fitted at the stern. As the principal biplane is not divided into compartments, and there is no cellular balancer, the action of the rudder would be futile, and turning impossible, if the inventors had not disposed, between the two surfaces of the elevator, two small vertical planes which help to support the whole system when turning, and to enable the rudder to move efficiently to turn the aeroplane. The two planes of which the rudder is composed are 1·80 metres high, 60 centimetres in breadth, and are spaced 50 centimetres apart. The rudder is operated by a second lever, having double articulation, held in the right hand of the aviator.

Thus, the pilot seated on the edge of the under frame (the Wright aeroplane has no body), his feet upon an open foot-rest, as is plainly shown in the photograph (Plate XXXII.), holds a lever in each hand. With the left hand he inclines the elevator as desired to cause his apparatus to ascend or to descend: with the right hand according to whether he pushes the lever backwards or forwards he makes his machine turn to the right or left. But, in addition, he can give this latter lever an independent sideways movement, whereby he warps the wings at will. We will see by what means.

Fig. 72 shows in detail the whole mechanism for warping the wings, when he moves the lever L^1 on the left-hand side of his seat A, placed between this lever L^1 and the inclination lever L. In the case of the diagram we suppose that the lever L^1 was pushed towards the left as shown by the curved arrow. Instantly the square bent-end *m*, which answers this movement, is turned also to the left and pulls in the direction of the arrows the controlling wires which are on its right. It thus depresses the right-hand rear corner of the upper supporting surface. This corner in depressing also pushes downwards the rear right-hand corner of the lower plane by means of a rigid and articulated member, which maintains the distance between the two planes. This right-hand rear corner in depression pulls the cord, which is on its left, in the direction indicated by the arrows, and through intermediate pulleys raises the rear left-hand corner of the lower supporting surface. The latter in this operation raises by means of the spacing member between the planes the left-hand corner of the upper plane, and so is obtained the warping which will cause the aeroplane to turn to the left. In pushing the lever L^1 towards the right, the warping action is reversed and tends to incline the aeroplane towards the right. The same lever L^1 controlling also the rudder by its móvement to and fro, compensates through the play of the latter the irregular rotations which might produce warping. The total depression of the extremities of the wings by the warping action is about 1 foot (30 centimetres).

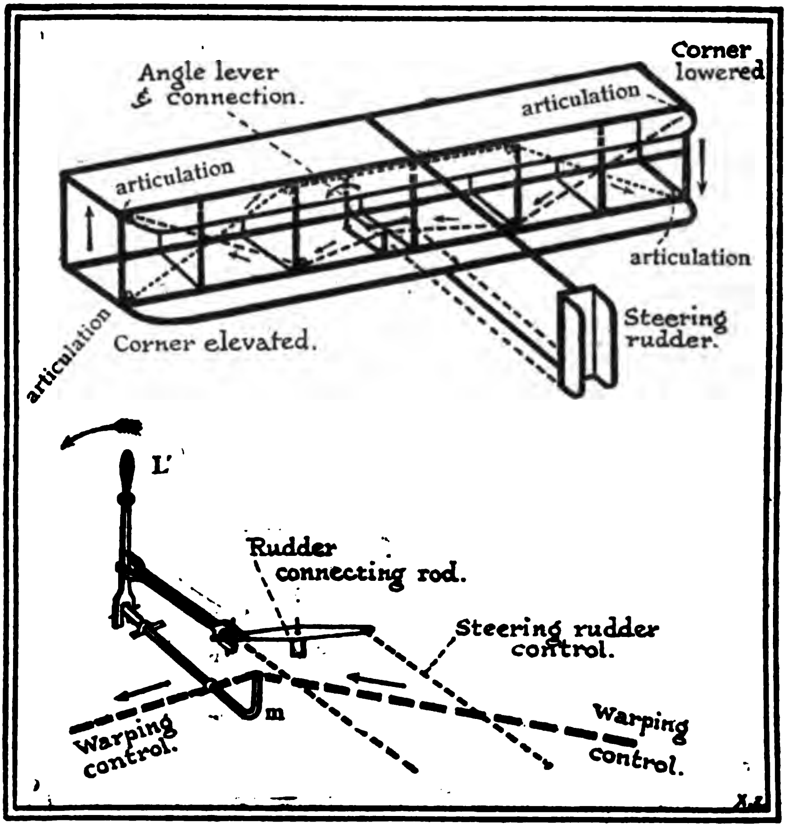


FIG. 72. Details of the wing-warping system of the Wright aeroplane

A cursory glance at these two levers the aviator holds in either hand shows what prodigious *sang-froid*, what absence of nerves is necessary—a false movement, a turn or an inclination in this aeroplane, having no "body," no forward cells or empennage, would bring about most terrible accidents. We had a striking example of this on May 6, 1909, in the alarming mishap which just failed to cut short the life of the Italian Lieutenant Caldera, one of Wilbur Wright's pupils, who was thrown to the ground by his unmanageable apparatus capsizing. Also one may state incontrovertibly that undoubtedly it is Wilbur Wright himself, or an aviator of the calibre of Comte de Lambert, his most expert pupil, who constitutes by his presence at the helm the greatest part of the value of his aeroplane.

Let us turn to the mechanical installation. The engine is a 4-cylinder petrol motor developing 25 horse-power. It runs at a speed of 1400 revolutions per minute and its weight is from 95 to 100 kilogrammes. Set a little to the right of the aviator, its weight balances the former when in his seat, which is on the left.

Propulsion is obtained by means of two screws of the same pitch and of the same diameter, but running inversely. They are of wood, with a diameter of 2·60 metres; they run in opposite directions, making 400 revolutions per minute. Owing to a convenient reducing gear, chains transmit the power from the motor to the propeller shafts. We have pointed out the danger of such an arrangement as this, which, in the event of one of the screws breaking, leaves the other revolving, and submits the aeroplane to an eccentric movement causing it to capsize. Wilbur Wright, since the accident which befell his brother and in which the American Lieutenant Selfridge was killed has, it appears, modified this dangerous system.

In order to start the Wright aeroplane a *rail* and *pylon* are necessary. The rail upon which glides a roller-carriage supporting the aeroplane is 70 feet (21 metres) long. It is laid on the ground and faces the wind. The rail is connected to the "pylon," a kind of pyramid framework, to the top of which is hoisted a weight of 800 kilogrammes and held in position by a trigger. In falling this weight releases a cord, which through an arrangement of pulleys hauls the aeroplane along the rail with increasing speed, since the velocity of a falling body is proportionate to the extent of its drop, which explains the uniformly accelerated movement.

This means of launching is ingenious, but it deprives the American system of much of its practical value. It is a pretty demonstration apparatus; a remarkable device for experimental mechanics. But the Brothers Wright must renounce this launching "rail," and fit their apparatus with facilities to permit it to set out *unaided* and under its own means, *i.e.*, they must strive to evolve a new model equipped with a wheeled chassis instead of skates.

The Wright apparatus moreover is rather dangerous because balancing, as much when travelling directly ahead as when turning, must always be secured by the aid of the aviator. On the other hand, in aeroplanes of French construction, as much in biplanes as in the excellent monoplanes, the aviator is concerned only with *lateral* stability, longitudinal stability being ensured by means of the empennage. This also explains the difficulty the American aviator has experienced in training his pupils. It is true he has taught some how to manipulate his "bird"; but this instruction, commenced at the Auvours camp during the month of August 1908, *lasted over seven months*, and it was not until March 18, 1909, that the American aviator dared to permit his pupils to manage their apparatuses themselves for the first time. Even the insistency with which it was announced that the pupils had flown "alone" at last sufficed to show the difficulty of the task. On the contrary the French aeroplanes are so stable in construction, that four or five lessons suffice to render an aviator capable of operating them with safety.

Nevertheless the Brothers Wright are entitled to considerable praise. They have perfected one important point in aviation, that of lateral equilibrium by the ingenious solution of warping the wings. They have given also a striking example of perseverance, for they built every part themselves, including their motor. Moreover, by their enthusiasm they have shown the true path which must be followed by aspiring aviators. They served their "bird apprenticeship" by practising, at first, straight flight—numerous "glides" carried out with aeroplanes without a motor. Thanks to these glides they were able to discover, step by step, the arrangements necessary to obtain the best sustentation and the minimum resistance.

But, after all, they were preceded by Chanute in America, and by Otto Lilienthal in Germany. In France aviators conceived a brilliant solution which secures lateral equilibrium as surely as by warping of the wings—the use of "ailerons."

To sum up, the Wright aeroplane in its first form was deserving of success, owing to simplicity of arrangements, and was able to accomplish some magnificent "records" in height and speed. Through not having to carry some 60 or 80 kilogrammes more weight, represented by the wheeled carriage of the French aeroplanes, freed from the great motive effort necessary to start, and consequently the increased motor weight, Wilbur Wright has been able to use an ordinary automobile engine, possessing greater reliability, and as a result has been more in a position to secure the records for altitude and length of flight. But if the machine has achieved some remarkable results, such are greatly attributable to the skill of the pilots, such as the Comte de Lambert. The machine as evolved originally is not able to effect a real "voyage," handicapped as as it is by the necessity of a launching rail compelling return to the pylon to re-start; if it comes to earth *en route* it cannot rise again.

This is where Blériot triumphs, for on October 31, 1908, he accomplished the first aerial voyage in what may be described as a closed circle from Toury to Artenay and back, *descending twice during the journey and re-starting under his own power*, passing over roads, villages, and woods. Such is an "aerial tour" in the fullest sense of the word, and that date, October 31, 1908, constitutes to my mind *an historical date in aviation.* Since then French aeroplanes have demonstrated their passenger-carrying capacity. Their solid constructional features enabled them to inaugurate the era of touring through the air.

MAURICE FARMAN'S AEROPLANE : THE BREGUET BIPLANE

M. Maurice Farman, the brother of the celebrated "champion of the air," has built an aeroplane on which he has accomplished some fine performances, the first of which type we will describe.

This apparatus, very well thought out, is a "biplane." Automatic longitudinal stability is secured on the general French principle with a tail balancer (Fig. 73).

The two similar, and superimposed carrying planes, spaced vertically 1·50 metres apart, are vertically strengthened by 8 pairs of ashwood uprights. These carrying planes have a spread of 10 metres by 2 metres breadth. Their individual superficies is consequently 20 square metres, and the aggregate sustaining surface 40 square metres.

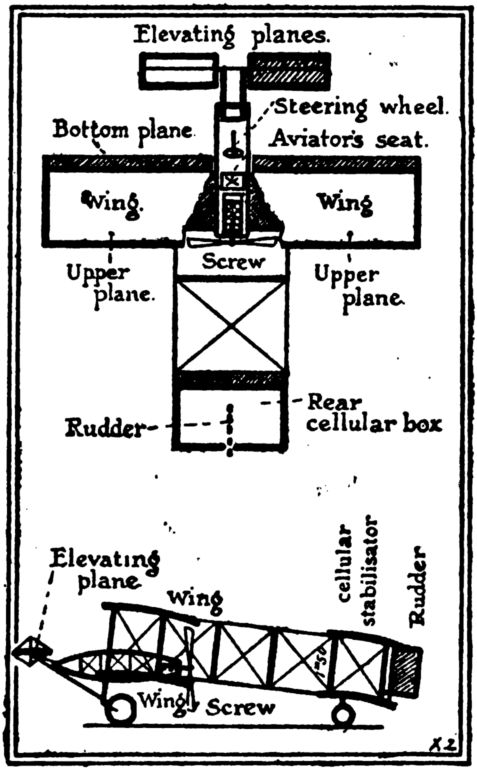


FIG. 73. The first Maurice Farman aeroplane

The planes are built up of light and rigid stays upon which is stretched, on both sides, a varnished cotton fabric weighing only 85 grammes per square metre.

These "wings" are mounted upon a cigar-shaped "body" of rectangular section, in which are placed the pilot's seat, motor, and the manœuvring and steering controls respectively. The motor and screw are placed *behind* the aviator; the wheel controlling the elevator and rudder, as well as the *lever for warping* the wings, is set in front of him.

The "balancing tail" is a "rear cell" connected to the planes forming the "front cell" by four long members cross-braced and stiffened by tightly stretched steel wire. The rear-cell has a spread of 3 metres, by 2 metres breadth, which in view of the fact that it is composed of two planes spaced 1·50 metres apart, gives a total surface of 12 square metres. The curvature of these two surfaces is calculated in such a way that they act slightly as "carriers" as well as effecting equilibrium.

The elevator is at the prow. It is a single plane of 4·90 metres spread, by 90 centimetres width. It is divided into two panels, one on either side of the extremity of the body of the machine. The rudder is formed of a vertical plane, moving between the two horizontal surfaces of the rear cell.

The engine has been specially designed for aeronautical purposes by Rénault Brothers, the well-known motor-car manufacturers. This motor comprises 8 cylinders in two series of four, working upon a common shaft: the cylinders, in pairs, being arranged in the form of a V, with the shaft at the apex of the angle. The cylinders are air-cooled. All complete, the motor weighs 178 kilogrammes, and has developed, under dynamometer tests, 58 horse-power, which gives a weight of 3·100 kilogrammes per horse-power. A special reducing gear driven from the motor shaft reduces the engine speed from 1600 revolutions to 800 revolutions per minute at the screw propeller.

The screw is of wood. It was built by M. Chauvière, who designed the remarkable propeller of the *Bayard-Clément*. It is of the type which its distinguished designer calls "integral screw," and measures 2·50 metres in diameter, with a pitch of 2·50 metres. It is placed immediately astern of the two carrying surfaces, the exterior edge of which is slightly indented to afford free passage for the revolution of the two blades.

The whole apparatus is carried upon a wheeled carriage which serves for launching and landing. It is four-wheeled, the two under the front cell being of 70 centimetres diameter each, while the two under the rear cell are a trifle smaller.

As the figure shows, the articulated forks upon which these wheels are mounted are fitted with absorption springs to allow descent without injury to the aeroplane.

Fitted with the Rénault motor and carrying the aviator weighing 80 kilogrammes, the apparatus has a total weight of 528 kilogrammes. At Buc it made some very successful attempts at flight which served to demonstrate the actual possibilities of the machine.

It will be remarked that the cells are not divided into compartments. The body of the aeroplane is the only surface opposed to lateral drift and giving a fulcrum for turning.

In a more recent Maurice Farman type of aeroplane, the aviator has abandoned the American system of warping the wings, which fatigues the structure, thereby tending towards deformation. He has adopted "ailerons" which have proved so positive in action, and which have given the best results both upon biplanes and monoplanes. The rudder is formed of two planes, while the elevator has only one plane. The balancing tail comprises two parallel horizontal planes.

The biplane, built by Henry Farman, and rendered famous by Paulhan's triumphant flight from London to Manchester, is quite different from the Voisin type. The illustrations thereof are sufficiently explanatory to dispense with a detailed description.

The two carrying surfaces comprise two parallel planes, slightly incurved, following the theoretical lines we indicated when discussing aeroplane wings. The upper plane is a trifle larger than the lower plane. The machine has neither body nor vertical partitions. The only surfaces offering resistance to lateral movement are those of the aviator himself—or those of his passengers—and that of the motor, petrol tank, and lastly the surface of the rudder. The "trim" of the apparatus is secured by means of the ailerons.

The elevator at the prow comprises a single plane moving about a horizontal axis. The rudder at the stern consists of a single vertical plane working on a vertical axis, bisected, to carry the balancer, which is a single plane. The rear cell is suppressed. The machine is driven by a "Gnome" motor. The biplane rests upon four wheels. Its total length is 10 metres; spread of upper plane 10·50 metres, while the lower wing has a spread of only 7 metres.

Such is the notable apparatus with which Daniel Kinet established a world's record with a passenger aboard on April 8, 1910 (152 kilometres in 2 hours 19 minutes), and on which Paulhan flew in a direct line for 300 kilometres (London to Manchester, April 28, 1910).

It appears as if the names of Blériot and Farman are destined to be associated with "historical aerial voyages."

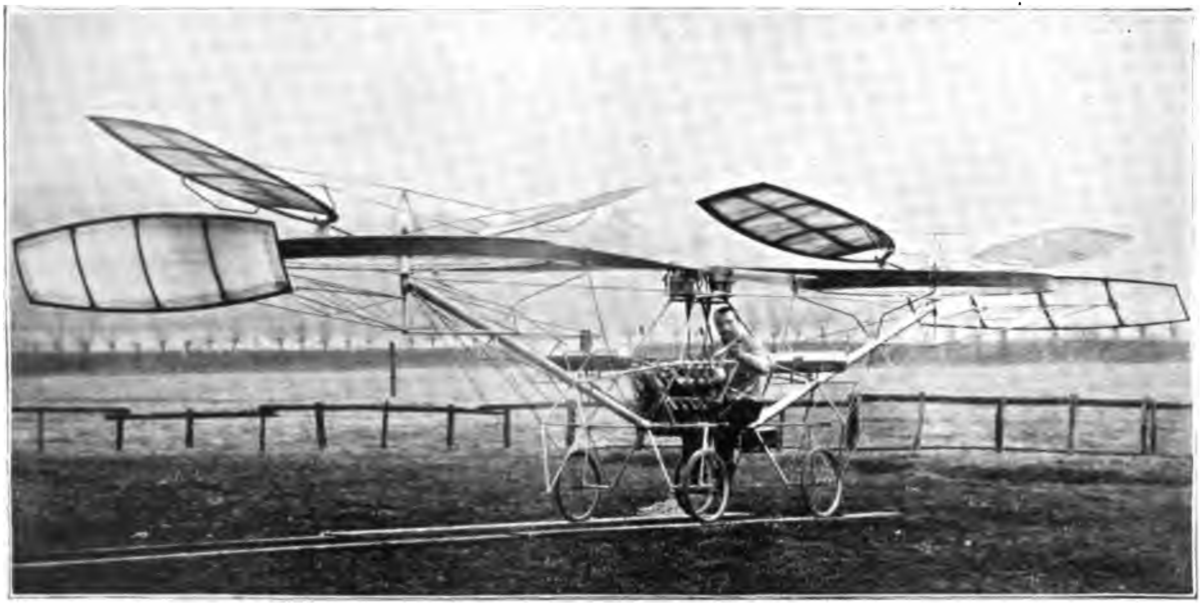
In 1909 Blériot crossed the English Channel, and in 1910 Paulhan crossed England on a Henry Farman aeroplane, winning the *Daily Mail* £10,000 prize. Also, upon a biplane of the same type, Paulhan first succeeded in attaining an altitude exceeding 1000 metres at Los Angeles, California, U.S.A. Later, Latham rose to 1000 metres upon his "Antoinette" monoplane. But since then these records have been eclipsed on several occasions.

The *Bréguet* biplane, evolved by the well-known constructional engineer of Douai, is of very special interest. It might be described as a "double monoplane" in view of the method adopted in the disposition and construction of the carrying surfaces. As a matter of fact the two planes are connected only by a single vertical metal tube. Such causes the apparatus to offer very slight resistance to the air, so that consequently the aviator is permitted to attain the high monoplane speeds, at the same time securing the greater safety of the biplane. Its spread is 12 metres; breadth of the planes 1·80 metres; total carrying surface 40 square metres; weight of the apparatus 580 kilogrammes.

Longitudinal stability is secured by a tail, the two surfaces of which can be inclined as the pilot desires. Stabilisation in an air eddy or when making a turn is effected in a dual manner: firstly by two ailerons placed between the two carrying surfaces; also by automatic and differential inclination, acting upon the upper wings, each of which automatically assumes its angle of incidence according to the higher or lower speed on the arc of the circle described in turning.

The framework of the wings is of metal, except those parts

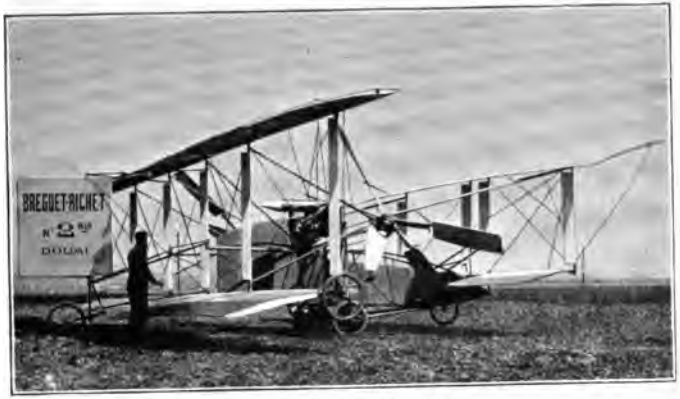
PLATE XXXIII



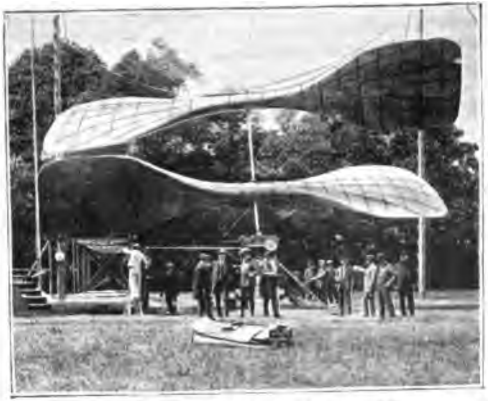
THE CORNU HELICOPTER

It rises vertically by means of horizontally revolving propellers.

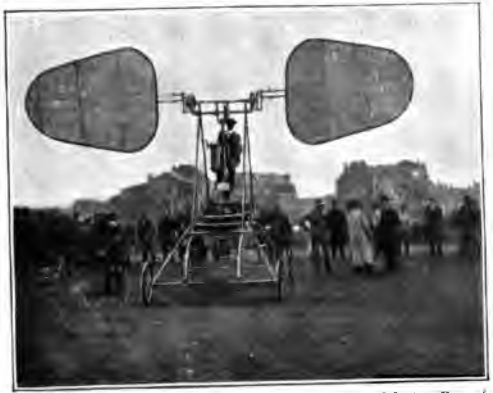
PLATE XXXIV



THE BRÉGUET GYROPLANE

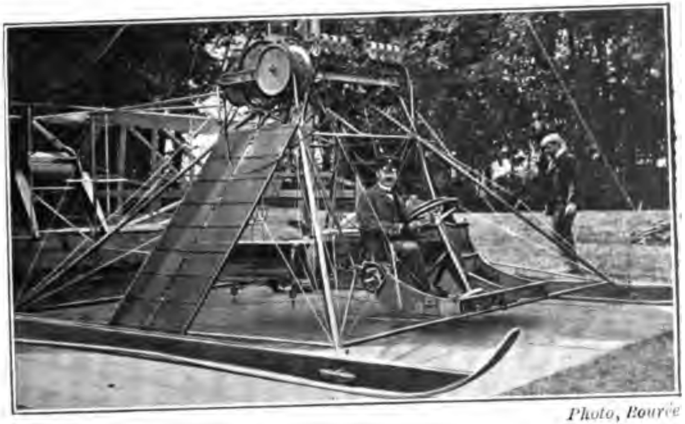


THE DE LA HAULT ORNITHOPTER



Photo, Bourée

THE PROPELLERS OF THE LÉGER HELICOPTER



Photo, Bourée

THE LÉGER HELICOPTER SHOWING THE MOTOR AND CONTROLLING MECHANISM subjected to least strains, where wood is used. A single wheel with a cardan joint controls all mechanism, and the whole system rests upon three wheels. Power is furnished from a 55 horse-power Rénault aviation motor. The propeller has three aluminium wings mounted on steel blades; is 2·50 metres diameter, and makes 900 revolutions per minute. M. Louis Bréguet, after some excellent flights, ascended with a passenger. The maximum weight-lifting capacity of this apparatus, consequently, may be estimated at 800 kilogrammes.

The Roger Sommer biplane is, perhaps, the lightest and the fastest biplane of to-day. It only weighs 320 kilogrammes, and can force itself into the air after a run along the ground for less than 60 metres. The two carrying planes have a spread of 10 metres, and their total surface is 31 square metres. The planes, covered on both sides by india-rubber fabric, are rigid, and lateral equilibrium is secured by ailerons, which, it must be admitted, are becoming more extensively adopted in preference to warping the wings. In the Sommer biplane the ailerons are controlled by the movement of the pilot himself.

The apparatus is furnished with a Gnome motor, a Chauvière propeller, a single plane balancing tail, rudder at the stern, and is carried on a flexible suspension type of four-wheeled carriage, and front skates. It has no *body*, but strange to say the apparatus *can be folded up*, which facilitates transport appreciably. This machine executed magnificent flights at Douzy, in the Ardennes.

CHAPTER V

DESCRIPTION OF SOME AEROPLANES

II. MONOPLANES

THE BLÉRIOT, ESNAULT-PELTERIE, AND "ANTOINETTE" MONOPLANES: CONSTRUCTION AND OPERATING MECHANISM

THE BLÉRIOT AEROPLANE

LET us now investigate the construction of the monoplane, that is to say, those in which the bird is imitated by only a single carrying surface instead of two, as in those already described.

The aeroplanes of the engineer Louis Blériot are deservingly famous. They enabled the expert aviator to make the first "aerial journey" in a closed circle with intermediate descents, and to achieve the first transmarine journey between France and England on July 25, 1909. Moreover, Louis Blériot is entitled to a dual distinction; not only did he evolve his aeroplane, but he constructed and tested it himself; every detail is his own work, and we will show how ingenious, simple, and effective everything is. We will first describe the original type as used on the Toury-Artenay journey.

The Blériot aeroplane in its general lines recalls a huge bird (Fig. 74). The carrying surface, set out in a single plane, is divided into two *wings*, one on either side, and the aviator sits between them. The wings have small "ailerons" at their tips, which serve to right the machine when it dips. The spread, body and small wings included, is only 9 metres, and the carrying surface has a total superficies of 26 square metres, the rear corners of the wings being slightly rounded.

The wings are made of stiff parchment, and are mounted upon a framework built of mahogany and poplar. The shape of the wings varies as they extend from the body, but they present a concave surface turned towards the earth throughout. The planes attack the air at an angle of 8 degrees. At their outer extremities are the balancing "ailerons" turning upon a horizontal axis, and their movement is controlled by the aviator by means of a device which we will describe later.

The wing frames are connected to the aeroplane "body." The latter comprises a long spindle forming a "trussed girder," rectangular at the prow, and triangular at the stern. The longitudinal members are cross-braced by ashwood struts, the whole being further strengthened by tightly stretched steel wire. The lattice structure thus obtained is of extraordinary lightness and solidity.

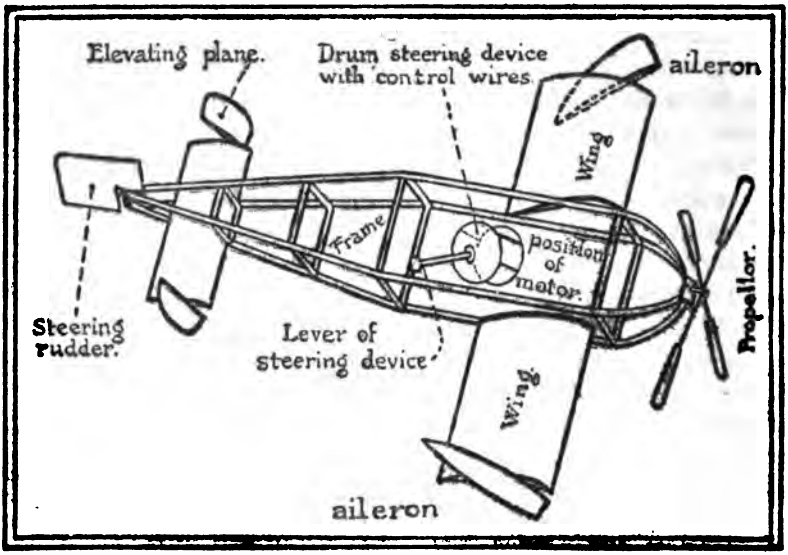
At the stern of this slender body is the "stabilisating empennage." This is rigid, and the length of the lever at the end of which it moves is a guarantee of its efficiency. The elevator is carried similarly at the rear extremity of the body. It may be pointed out that, in addition to this main elevator, the aviator can use also the two "ailerons" attached to the extremities of the two wings. When one is turned upwards and the other downwards, the apparatus is restored in case of lateral inclination; both moved in the same direction, they give ascent or descent and act in the same manner as the elevator. Accordingly in ascending or descending in a straight line these two mechanisms can be operated in such a manner that their actions are combined.

Lastly at the extreme rear end of the body is the rudder, a rigid plane turning about a vertical axis. The pilot takes his seat in a space provided in the body between the two wings, having in front the novel lever by means of which the whole of the various controlling movements are actuated.

This *unique* manœuvring device of the Blériot aeroplane is one of rare ingenuity and simplicity. It is a *lever and drum*, which we will describe in detail.

No one will deny the importance of maintaining positively and easily the direction of an aviating apparatus. The extreme mobility of the aeroplane in the atmosphere demands that the apparatus should answer to its controlling mechanism absolutely, because therein depends, not only the steadiness of the aerial route followed, but also the security, even the life, of the aviator.

We have seen, *à propos* of the Wright aeroplane, the inconvenience of a multiple lever system. Such is so complicated that its management requires prolonged practice, since each lever movement performs a definite operation.



[FIG. 74. Blériot's first monoplane

M. Blériot thought that directly the aeroplane became a moving plane in space the most simple device for maintaining a direct course would be one where a centrally placed connecting-rod, answering a decided action by the aeronaut, would communicate the movement of one plane to the other, thus causing them to move together. This is the only example perfected yet for controlling one moving plane by another.

The principle of this system is shown in Fig. 74. Close examination will show that the aeroplane while travelling in a straight line itself corrects any deviation from stability, whatever inclination the apparatus may assume, and irrespective of the number and position of the rudders, so long as the latter be correctly connected to the controlling plane. Thus in a single move, and to any desired extent, the stability of the aerial vessel may be effected. Moreover this can be accomplished without depriving the aviator of the control of his apparatus or compelling him to maintain that much-desired automatic stability, but which, despite some attendant advantages, is not free from many dangers.

With the lever and drum command, the base of the latter acting as the indicator, and turning in any desired direction, control is absolutely "instinctive," and the aviator cannot possibly make a mistake. Moreover, in combining this control with a level such as one uses in photography, the pilot can discern immediately which way he must move his lever to correct the aeroplane and thus preserve absolutely perfect stability while travelling.

The control is effected by means of a drum connected with a control lever having a ball-and-socket coupling, and consequently able to move in all directions. The drum and lever are thus connected together. At the base of the drum all the flexible steel wires which actuate the different mechanisms for "governing" the direction of the aeroplane are attached. Two levers are connected to the manœuvring arm for the simultaneous control of the motor, which must, indeed, work in concert with the movements of the elevator for fear of terrible accidents, such as loss of speed in ascending, or excessive speed in descent.

The Antoinette 16-cylinder motor of the original machine is of 50 horse-power, and has forced petrol feed. The radiator is carried in the tapered body of the vessel. The engine drives a four-bladed metal screw having a diameter of 2·10 metres, by 1·40 metres "pitch." This screw is mounted at the front of the body; therefore it "draws" the aeroplane.

The whole apparatus rests upon a wheeled carriage for launching, and to ensure descent without shock. This carriage has two bicycle wheels placed under the front of the tapered body. A third auxiliary wheel near the stern secures balance of the apparatus when it rests upon the ground. The carriage is a built-up rigid cross-braced framework of wood and steel tubes. This frame supports a trussed girder which forms the body of the aeroplane (Fig. 75), which reposes in quite a springy manner upon a pair of parallel coupled wheels turning about vertical axes. The connection between the carriage proper and each of the two wheels is by a collapsible triangle, the centre of the wheel forming the apex, a trifle below the principal leg, and in which the third leg slides in a vertical tube, bearing in its movement against the head of a spring fixed to the carriage. By this arrangement the whole, although not weighing more than 35 kilogrammes, can absorb a blow of several hundred kilogrammes on landing. Fig. 75 shows the side elevation of the tapered carriage with the wheeled frame under the front, and also the rear wheel.

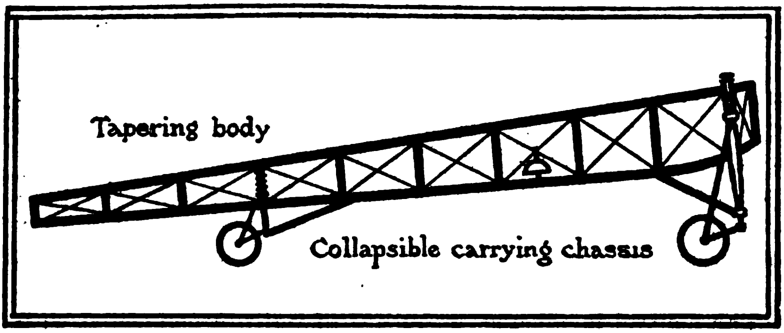


FIG. 75. Wheeled carriage of the Blériot aeroplane

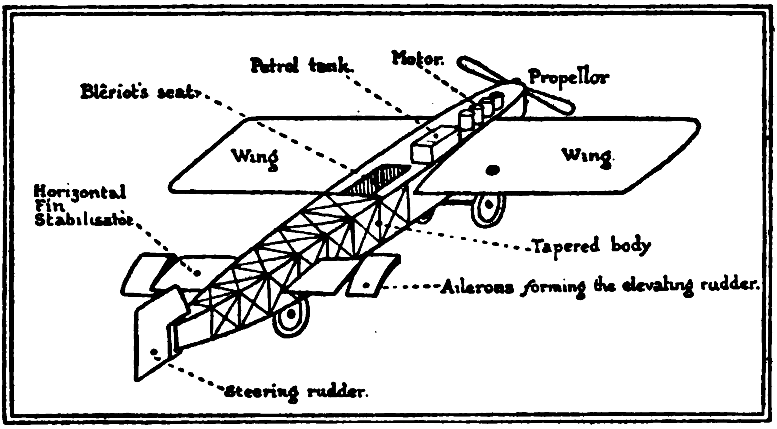


FIG. 75B. Blériot's improved monoplane

Having given the general outlines of this remarkable aeroplane, known as *Blériot IX.*, let us conclude by saying that the total length from end to end is 12 metres. Its complete spread is 9 metres; carrying surface 26 square metres; weight, including aviator and supplies of fuel, 480 kilogrammes; and its initial speed 70 kilometres per hour.

Blériot XI., such as was used in the Calais-Dover flight, is of more recent design. It is a monoplane in which the ailerons of the carrying surfaces are abandoned in favour of simple warping. The ailerons are retained at the two extremities of the rear stabilisator, and form the elevator. The dimensions of this new aeroplane are much less than its predecessors, being—over all, length, 8 metres; spread, 7·20 metres; carrying surface, reduced to 12 square metres; angle of attack, 7 degrees; wooden screw propeller; motor, 7-cylinder, 30 horse-power, Esnault-Pelterie (R.E.P.). Under these conditions the supporting surface sustains an effort of 27 kilogrammes per square metre, but such is the perfection of construction that this end is successfully achieved. The speed of the apparatus is 80 kilometres per hour.

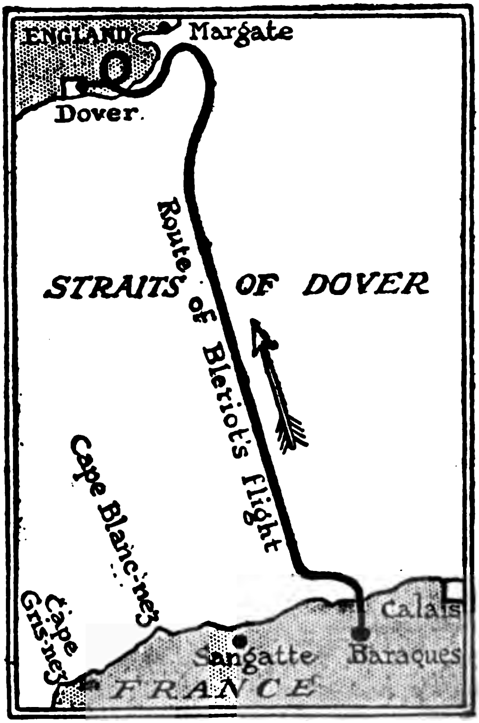


FIG. 75C. Map of Blériot's Channel flight

The *Blériot model of* 1910 differs from *Blériot XI.* in that it is shorter (6·50 metres), and that the tapered body is covered throughout with fabric. The tail-balancer resembles a distended swallow's tail, and is connected to the axis of the elevator, which consists of two large segments. The rudder is also of greater surface.

THE ESNAULT-PELTERIE AEROPLANE

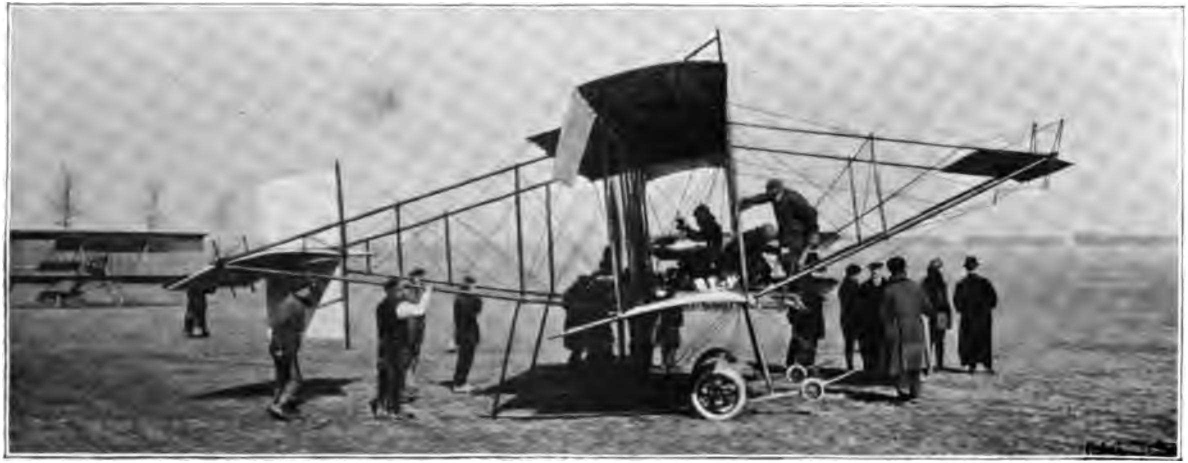
There is a tendency among monoplane designers to decrease the superficies of carrying surfaces to avoid increase of resistance. This tendency is manifested in one of the most remarkable aeroplanes among those which have yet been built, that of M. Robert Esnault-Pelterie, which its inventor, borrowing the three initials of his name, describes under the abbreviation "R.E.P." This machine was one of the first to be constructed in France.

Among the already important group of French aviators, M. Esnault-Pelterie occupies quite a distinct position. Though very young he set out on the "path through the air" as far back as 1903, for rumours of the exploits of the Brothers Wright, mysteriously held in secret, roused ambitions which became resolved into persevering, continued, and rational experiments, and led him to success. The young aviator (who at that time, however, felt himself to be one of the veterans in the art) did not seek anything from anybody. Unaided, he conceived, constructed, and tested his aeroplane. Moreover, being a practical mechanician, he evolved and made every part of a new type of explosion motor. It was novel because of its compactness, exceptional lightness, and at the same time reliability of action. So in the aviating apparatus that he fashioned and brought to success everything bears the imprint of his personality—the general lines, construction, motor, and even the arrangement of the wheeled launching carriage.

The Esnault-Pelterie aeroplane is a monoplane, distinguished by its flexible warping wings, and stern carrying surface fulfilling the function of the elevator. It is fitted with a stabilisating empennage, and its carriage is mounted upon two wheels "in tandem," while the tip of each wing carries a wheel for contact with the ground.

The shape of the body of the aeroplane is fusiform. It is built up of steel tubes (bicycle tubes), autogenously welded together. Moreover, they form a triangular network similar to a latticed girder, which assures complete indeformability as well as rigidity and strength of the system.

PLATE XXXV

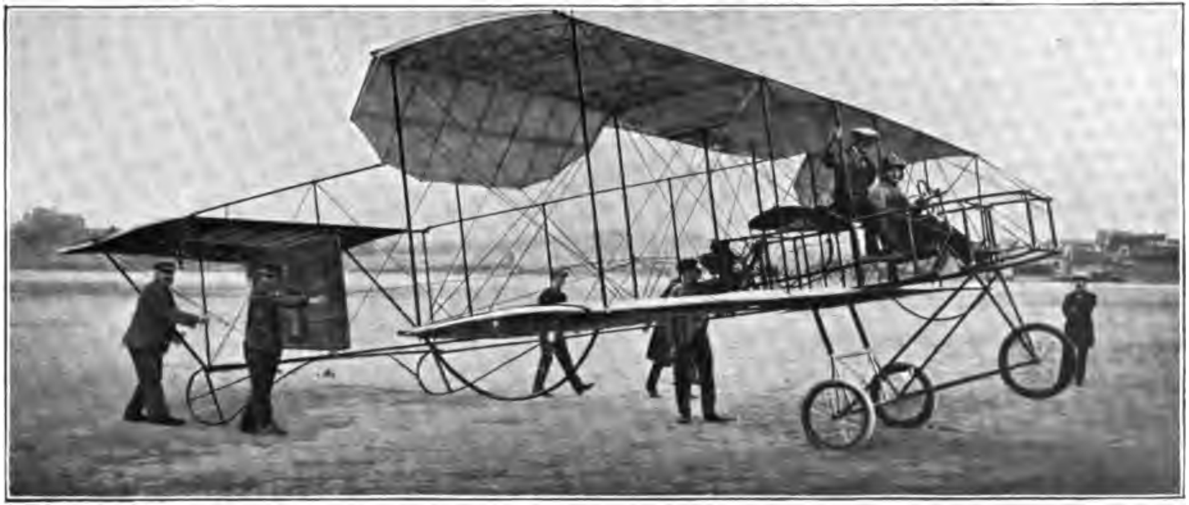


Photo, Rol

HENRY FARMAN'S NEW BIPLANE

The rear cell is suppressed. The tail is a monoplane, and the upper wing carries ailerons

PLATE XXXVI



THE LATEST VOISIN BIPLANE, WITH THE AVIATOR BIELOVUCIE AT THE WHEEL *Photo, Branger*

The rudder and elevator are in the rear cell, the boxing of which is suppressed. The ailerons permit redressing of transverse inclination

The wings have a total spread of 9·60 metres, and their design is in accordance with the results of lengthy experiments carried out by the inventor. Their surface is 15·75 square metres. As they support the whole weight of the apparatus, which aggregates 420 kilogrammes, this represents a proportion of 26·6 kilogrammes per square metre, the same, be it noted, as in the new monoplane, *Blériot XI.* The wings are of wood, flexible, strong, and light. They are made in slips, strengthened lengthwise by steel and aluminium. The fabric is stretched over these wings, this being the surface offered to the resistant action of the air. Each wing is stretched underneath by two sets of ropes converging to a point beneath the carriage, and by which warping is accomplished. Each of these sets of ropes supports one-fourth of the weight of the apparatus.

When viewed from above the Esnault-Pelterie aeroplane strikingly resembles a bird with its fan-shaped tail formed by the spreading of its feathers. The surface thus shown (Fig. 76) has a variable inclination at its rear end, thereby forming the elevator, under which is placed the well-balanced rudder, turning about its vertical axis. The latter, to recall marine practice, is what is called a "compensated" rudder, because the axis of rotation passes through its centre instead of at one or other of its sides. Under the body is a "keel," which secures longitudinal stability. The pilot has his seat towards the front of the body of the aeroplane, while the screw is at the extreme prow; therefore it "draws" the machine through the air. The pilot, owing to the tapering of the stern, has a clear view of the ground in front as he drives the aeroplane along preparatory to launching.

The steering and manœuvring control are by means of levers and pedals. The manipulation of an aeroplane comprises two operations essentially different, corresponding to two requirements widely divergent. There is first assurance of stability at starting, and afterwards the maintenance of forward direction. For each of these two manœuvring operations M. Esnault-Pelterie has provided a vertical lever. Stability itself also comprises two variants; longitudinal and lateral stability respectively. The lever which controls the balance has two movements, one to and fro, the other from left to right. For this purpose it is fitted with a universal joint, and is set to the left of the aviator. When he moves it from left to right, or inversely, it warps the wings through the four sets of under-stretched ropes; when he moves it from front to back, or *vice versa*, it actuates the elevator, and as a result enables the aviator to recover his longitudinal balance, or, if he so desires, to ascend or to descend.

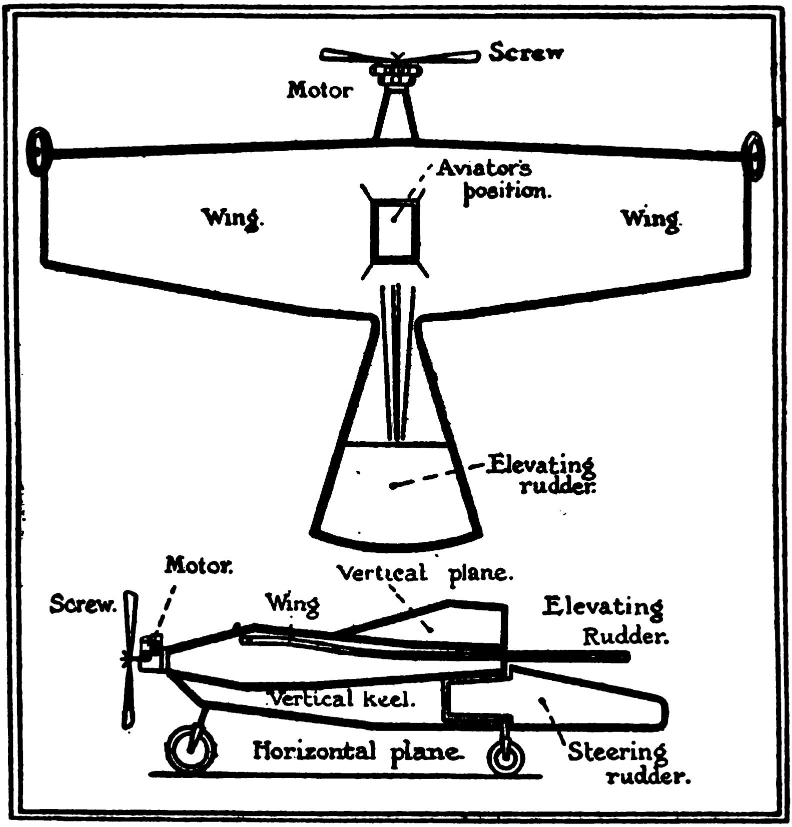


FIG. 76. The Esnault-Pelterie monoplane

The second lever is placed in front of the pilot; controlling lateral direction, it is moved transversely, and commands the rudder. One can see the ingenuity and extreme simplicity in the design of these steering devices; the aviator must push the levers in the direction in which he wishes his aeroplane to go; therefore, the movements which he has to carry out to this end are, so to speak, reflexive, and error is impossible. Finally, two pedals allow the aviator to control his motor, one acting upon the gas inlet, the other upon the propeller clutch.

So far as the motor is concerned, we have already had occasion to describe it. The Esnault-Pelterie (R.E.P.) engine is one of the most original and one of the best-conceived motors in aviation practice. When it was first completed it received the prize of La Société des Ingénieurs Civils. It is of 30–35 horse-power, and its cylinders, numbering five, seven or ten, according to the power, are disposed in two "semi-stars," but in such a manner as to be all above the horizontal diameter of the figure. In this manner lubrication is perfect. The valves are of the sliding type, and, according to their position, permit admission and exhaust; there is one to each cylinder, and all are operated by a common cam. There is no water-circulation, the cylinders being fitted with fins, and at a speed of 45 kilometres per hour cooling is very perfect. The 30–35 horse-power motor weighs 68 kilogrammes complete. An oil reservoir of 6 litres and a fuel tank of 40 litres suffice for two hours' continuous flight under the propulsion of a four-bladed screw 2 metres in diameter, mounted direct on the motor shaft.

In completing our description of this remarkable aeroplane, it is only necessary to say a word about the wheeled carriage used in launching and landing. The body of the apparatus is carried upon a pair of wheels arranged in "tandem." Under these circumstances it tilts to the left or right; but the tip of each wing being fitted with a special wheel, permits the apparatus to run along the ground without bringing the wings into contact with the latter. Immediately the apparatus is launched, the aviator, by the aid of the warping lever, lifts the wing which is trailing, and the equilibrium of the machine is established. The front carrying-wheel is mounted upon an "oil-pneumatic brake," assisted by a spiral spring. Under ordinary circumstances the weight of the apparatus is supported flexibly upon this spring. Vibrations caused by the unevenness of the ground are absorbed by an air cylinder, in which moves an air-compression piston. Finally, the shock in landing is taken up by an oil brake, in which this liquid, compressed by the blow, is forced through a very small orifice: this brake, which weighs only 6 kilogrammes, can absorb 350 kilogrammes. One can see, therefore, that it is very efficient for the landing of the aeroplane.

THE "ANTOINETTE" AEROPLANE

Among the aeroplanes of the monoplane type, the *Antoinette* deserves particular mention. Every one knows that the motors of this type have furnished aviation already with an engine in which power combined with lightness has been carried to such a degree that a 100 horse-power motor can be carried by an average man. The builders of these engines have undertaken also the construction of aeroplanes, and in their choice they decided upon the monoplane.

They began by building the *Gastambide-Mengin* aeroplane, which served as a means of investigation and research. By improvement upon improvement, they at last produced a striking type, which is known as *Antoinette V.*

These constructors, like so many other aviators of to-day, preferred the monoplane because of its extreme simplicity, facility of construction, and greater efficiency, requiring less power for progression through the air under the same conditions of weight and speed.

One of the most remarkable features of the *Antoinette* aeroplanes is the design and build of the carrying surfaces. These, divided into two elements constituting wings in the fullest sense of the word, are of trapezium form, the larger base being contiguous to the body of the machine. When seen from the front the apparatus has the appearance of a very open V.

The section of these wings is of such form as to secure the maximum of "power of penetration." Their surfaces are covered on both sides, and the fabric is mounted upon a framework which is certainly a marvellous piece of work from the triple standpoint of rigidity, solidity, and lightness. This framework is composed of an assemblage of longitudinal and transversal ribs, intersecting one another so as to form a series of triangles, the whole being consolidated in a rigid manner by riveted aluminium "gussets." The wing surface is 25 square metres, and yet their combined weight is scarcely 30 kilogrammes. Thus, one can see that the total carrying surface is 50 square metres. The extreme spread is 12·80 metres. It is very interesting to note that the builders have designed their framing upon the lines and principle followed by the constructors of metallic bridges and the Eiffel Tower, which consists of subjecting every part to tension and compression.

The body is triangular in section; it is a long girder, ending at the front in a pyramid, prismatic at the wings, and then tapering towards the tail of the apparatus. It is built upon the principle of metal bridges, but at the same time it is light and rigid. Body and wings are covered with fabric, carefully stretched and freely varnished. This imparts to the surfaces moving through the air a remarkable smoothness, reducing the friction of the molecules of air coming into contact with the force which displaces them to the minimum.

The constructors of the *Antoinette* aeroplane have abandoned warping the wings for the following reason. With Louis Blériot, they have adopted *ailerons* fitted to the tips of the carrying surfaces, though in a slightly different form. These ailerons are connected to the extremity of the wings, and when at rest form a prolongation thereof. They are connected with the latter by an articulated system which lowers one while it raises the other. This produces the same effect as warping, but with greater power and without the inconvenient danger of fatiguing the wing framework by twisting or bending a part of its construction. These ailerons assure the utmost lateral stability.

Longitudinal stability is obtained by an "empennage." It extends horizontally and vertically beyond the surfaces of the empennage properly so called, and carries two rudders for elevating and steering respectively. The great length of the apparatus, which is 11·50 metres, gives a very high efficiency to this empennage, securing a remarkable stability in the direction of travel.

Control is effected by three wheels. One cannot refrain from thinking that such is too much for an aviator who has only *two* hands! Two wheels, controlling steering and the ailerons respectively, are close together, it is true, so that the hand can pass easily from one to the other. For my part, I think it would be wiser, perhaps, to have recourse to a control arrangement of the Blériot aeroplane type. That is the only criticism which I can offer of this apparatus, the conception and the construction of which are remarkable from all points. In addition, two handles control the ignition and the inlet throttle of the motor, while there is a foot-brake to stop the engine.

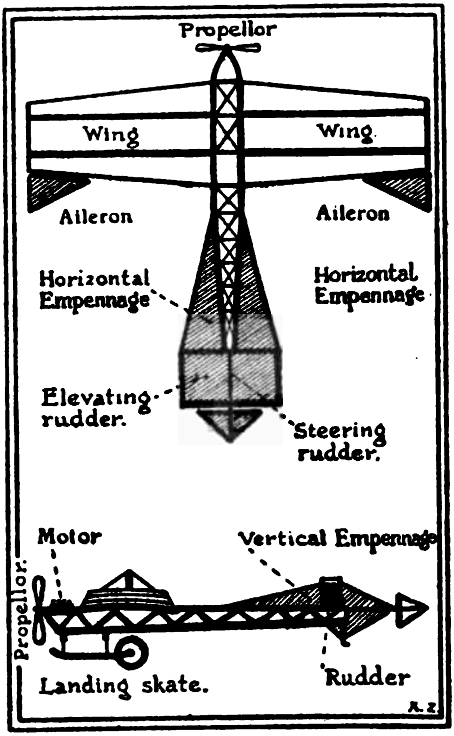


FIG. 77. The Antoinette monoplane

The whole apparatus is carried upon a carriage composed of a "wheeled skate" placed under the front of the body, two "shores," one at the right and the other at the left centre of each wing, and a "butt-end" under the tail. The "shores" and "butt-end" are on the longitudinal axis of the machine. The "roller-skate," comprising a bicycle wheel at the back and a roller at the front, admits of absorbing to the maximum the severe shocks which are produced at the moment of landing, owing to an ingenious and solid suspension spiral spring. The skate-wheel, almost under the centre of gravity of the apparatus, is so placed that the strain upon the tail is reduced to the minimum. Not only do the "shores" preserve the wings from all rough contact with the ground, but they serve as an anchoring point for the upper consolidating ropework. Moreover, a vertical piece serves as a straining support for the cords stretched over the upper face of the supporting surface.

When it is desired to launch the apparatus, the motor is started and the propeller is coupled in. The aeroplane is supported on the ground by its skate, shore, and stern butt-end. As the motor speed increases the butt-end first leaves the ground; a little lateral oscillation and the shores rise in their turn. Then the apparatus, poised upon its roller-skate, steadily balances itself, until at last the engine power has developed sufficiently to enable it to rise.

The motor is, naturally, an "Antoinette." It has eight cylinders disposed in a V, and develops 55 horse-power. It is placed towards the front, and drives a two-bladed propeller of 2·20 metres diameter. This screw is of metal; its shaft is a steel tube with blades of aluminium. Its pitch is 1·30 metres, and it runs at 1100 revolutions per minute. The set of the two blades, and consequently the pitch, is variable.

Exceptional precautions have been observed to secure ample accommodation for the aviator. His position is well sprung, so as to preserve him as far as possible from all shocks, and at the same time allow him the greatest freedom in mevement.

Such is this superb monoplane, the construction of which is perfect from all points of view. Its simplicity of control is striking. One of the first models was taken to the Châlons camp, and there placed in the hands of M. Demanest, who served his apprenticeship as pilot.

After five lessons only, the young aviator was able not only to "fly," but to win, on April 8, 1909, the prize of the Aero Club of France for 250 metres. M. Henry Farman, passing through the camp at Châlons, officially timed the trip, and warmly congratulated the new aerial navigator.

And on June 5, 1909, the *Antoinette* aeroplane accomplished another performance. M. Latham, scarcely familiar with the management of this remarkable aeroplane, flew for *one hour seven minutes*, when darkness stopped him. Not content with having beaten the world's record in a monoplane, he set out on the following day with a passenger. The third day he performed an unprecedented achievement in aerial flight, by carrying two passengers, MM. Fournier and Santos-Dumont, and demonstrated once and for all by his marvellous skill the safety and facility of manipulation, and consequently the absolute superiority, of the French aero-monoplanes. Since then this aviator has carried off innumerable trophies.

This feat, so rapid, this safety, so promptly acquired, demonstrates better than words the great security of the French aeroplanes, and how much easier they are to control than apparatuses which demand *everything of* the aviator. And this rapid initiation is not an isolated instance. Flying can be learned in a few lessons upon the *Blériot*, *Esnault-Pelterie*, *Voisin*, *Farman*, *Tellier*, and *Antoinette* aeroplanes. This exemption from a long, laborious, and perilous apprenticeship is quite a triumph for French aviation.

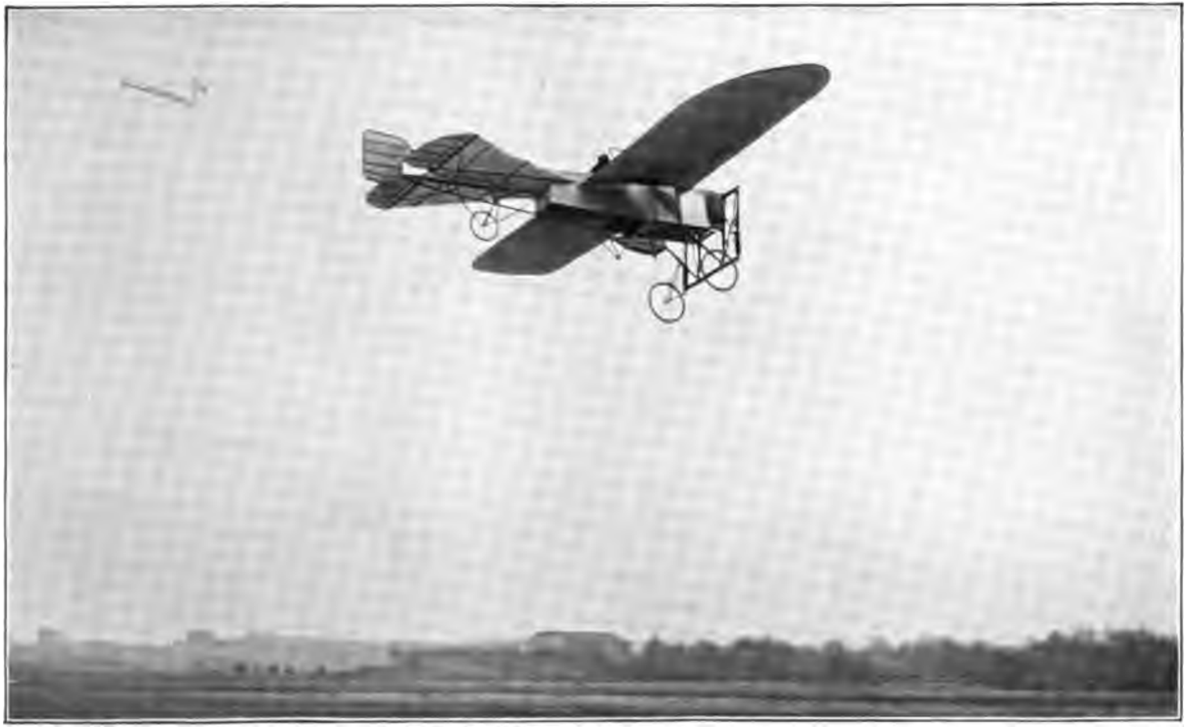
M. SANTOS-DUMONT'S "DEMOISELLE": THE TELLIER AEROPLANE

Smaller still is the latest aeroplane designed by M. Santos-Dumont, the *Demoiselle*, as it has been christened by its author. It is 6 metres long, 5 metres spread only, and 150 kilogrammes in total weight. Such is the remarkable machine on which the Brazilian aviator completed several successive flights at St. Cyr, early in April 1909. And during September 1909, the intrepid Brazilian accomplished the extraordinary feat of covering *8 kilometres in 5* minutes. Power is furnished from a Darracq motor, and the aviator is suspended beneath the engine in a sling, operating one of the controlling devices by the movements of his shoulders. With this machine Santos-Dumont beat the record in "tearing away" from the earth by rising into the air after a launching run along the ground of only 65 metres. He carried out diverting flights by setting out from St. Cyr to visit the Count and Countess Galard, at their country seat, Wideville, 17 kilometres from Versailles:

Thus is demonstrated the fact that one can fly without the use of immense surfaces, of weighty and cumbersome machines. Before long, thanks to the explosion motor, the artificial bird of less weight and bulk will be able to go anywhere. A little more progress and every one will fly.

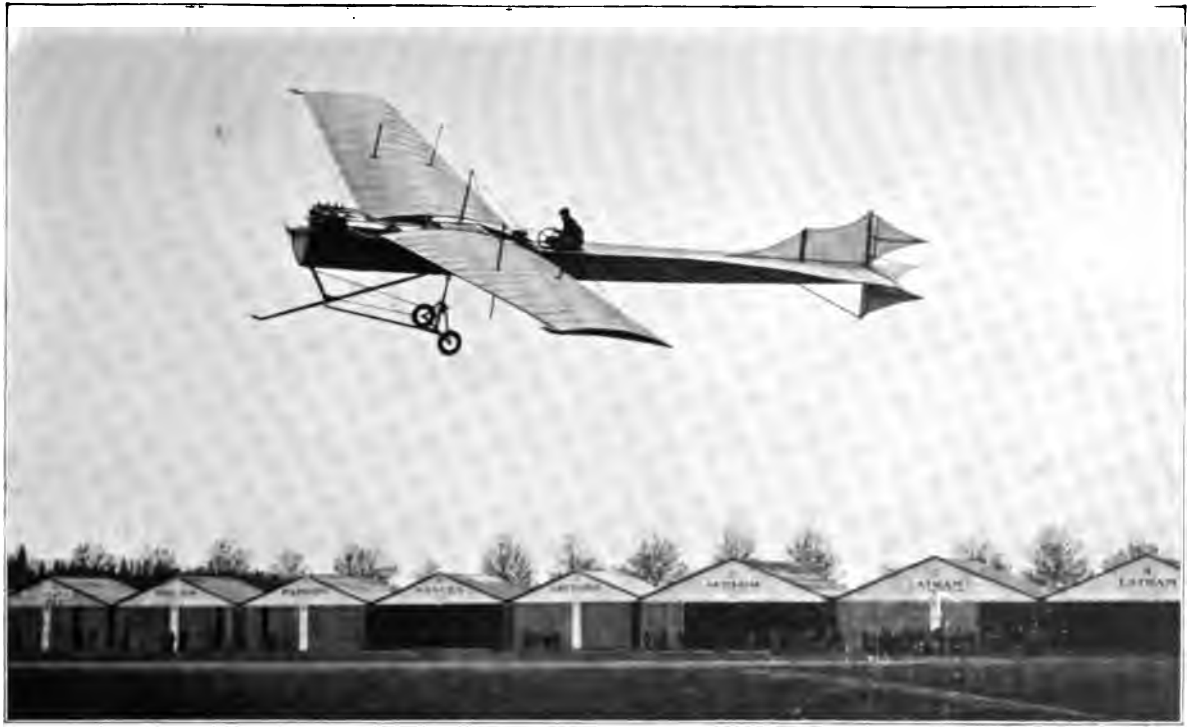
A few words must be said likewise about an entirely new

PLATE XXXVII



THE 1910 "BLÉRIOT" MONOPLANE FROM BELOW

PLATE XXXVIII



THE 1910 "ANTOINETTE" MONOPLANE, MOUNTED BY LATHAM monoplane emanating from the ateliers of the Brothers Tellier. This machine possesses some truly remarkable features.

In its broad lines the apparatus recalls the *Blériot* monoplane which flew across the Channel. But it differs therefrom in essential details. First and foremost the wings are articulated. The designer has reverted to the system of warping the wings in his first model; but undoubtedly he will improve this otherwise successful model, by substituting the simpler and more reliable ailerons for the wing-warping arrangement.

The rudder at the stern is wholly above the empennage tail and elevator. Furthermore, longitudinal stability and opposition to lateral drift are secured by means of a rigid vertical "element."

The weight of the Tellier aeroplane, ready for the air, is 500 kilogrammes, which includes sufficient fuel for six hours' flight. The two-bladed propeller, also a creation of the Tellier shops, is made of wood; the Panhard-Levassor 35 horsepower motor runs at 1000 revolutions per minute; and the whole mechanism is controlled by a single wheel.

The apparatus is carried upon a latticed wheeled carriage. The front part of the body is covered with fabric. It is scarcely necessary to say that, in common with all French monoplanes, longitudinal stability is assured automatically by means of the empennage tail. The wing spread is 11 metres, length of machine 11 metres, and the superficies is 24 square metres. Seen from the front the machine has the form of a very widely opened V.

Such is this simple and striking aeroplane, the control of which is so simple that M. Émile Dubonnet secured his aviator-pilot's certificate in a single flight with turns without detaining the governing committee more than half an hour at the aerodrome, after but four trips on the machine!

In the first flight succeeding the granting of this certificate M. Émile Dubonnet accomplished a master-stroke. The scientific journal *La Nature* offered a prize of £400 to the first aviator who made a cross-country journey of 100 kilometres (such conditions would have to be fulfilled to render aviation practical) within two hours or less. Émile Dubonnet won this prize easily upon his Tellier monoplane on April 3, 1910.

Thereby he secured the record for a mechanical flight across country, of which, however, he was deprived four weeks later by Paulhan's magnificent flight from London to Manchester.

THE TWO SCHOOLS OF AVIATION

We see from the foregoing that we are confronted by two schools of aviating apparatus: the American school, represented by the Brothers Wright, which demands *everything* of the aviator, and the French school, Voisin, Farman, Blériot, Esnault-Pelterie, Antoinette, which requires, on the other hand, the *minimum* from the pilot.

Which of the two is correct?

The best way to reply to this question is to quote the words of Paul Painlevé, Sorbonne Professor, and member of the Académie des Sciences. M. Painlevé is not an abstract mathematician who confines himself to differential symbols or the study of elliptic action. He has probed into aviation practice, has flown in turn with Wright at Auvours, and with Farman at the Châlons camp, and this is how, in a subsequent article, he expressed himself upon the subject:

"Aviation is the most burning mechanical problem appealing to mankind to-day. *Its solution is achieved.* To-morrow it will be commercial; in a few years it will commence to transform the world. Now this solution can be indicated upon broad lines.

"We have two schools, the French and the American, or if one so prefers—for it is confined to the two constructors who have effected the most impressive results—the Voisin and the Wright systems respectively.[1]

"In the first place an aeroplane must travel quickly to be able to support itself in the air; the speed must be such that the resistance of the air, increasing with the speed, prevents it from falling, whence the necessity of a motor, powerful, light, and regular in action. The more swiftly an aeroplane can travel the more stable and capable will be the apparatus for combating the caprices of the wind. The perfection of an ideal motor is no more than a question of months.

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[1] At the time the eminent mathematician wrote these words (*Le Matin*, October 28, 1908) M. Blériot had not made his "historical journey" in a *closed circle* or his flight across the Channel, and Latham had not accomplished his well-known brilliant triumphs on his *Antoinette* monoplane.

"Then it is imperative (and this is the gravest difficulty) that the apparatus should neither dip forwards nor backwards, neither to the right nor left; it must not even deviate from its direction of travel. In a word, the aeroplane must not pitch or roll, or swing round suddenly, or else the pilot must be able to restore such unbalancing movements as soon as they develop.

"Here are the means of obtaining this stability, which are different in the two schools.

"Wright has sought simplicity and lightness above everything, but *the equilibrium of his apparatus is entirely in the hands of the pilot.* Three distinct movements combat the three possible perturbations; warping of the wings counteracts rolling particularly.

"On the contrary, the Voisin Brothers secure lateral stability by partitioning the two wings like the cells of a kite in the form of a cigar-box. *Their apparatus adapts itself to the most convenient inclination in turning.* Two operations instead of three are all that is necessary to control their machine—of the rudder and elevator respectively. *Even this last control is now simplified greatly by the addition of a long tail, which opposes pitching.*

"Lastly, the utilisation of motive power either by large slowly-turning screws as in the Wright machine, or the smaller and higher speed of the propeller of the Voisin system, appear comparable.

"The Voisin apparatus is decidedly heavier than the Wright (650 instead of about 500 kilogrammes), due in the first instance to the tail, and secondly to the wheeled carriage (80 to 100 kilogrammes) necessary to enable the apparatus to lift itself under its own effort.

"These differences, well specified here, are the results obtained by the two apparatuses. Wright holds the record for distance unaccompanied and with a passenger,[1] *yet he has never raised himself by his own effort.* He will be able to do so though when he so desires, but *will it be without increasing weight?*"

"The Voisin apparatus, piloted by Farman, holds the record for speed—70 kilometres per hour at least. But it must be pointed out that it is always self-lifting by means of its wheeled carriage, weighing 80 kilogrammes.

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[1] These lines were written during October 1908.

"I saw Farman fly in a violent wind (October 28, 1908) over the camp at Châlons; he made the first long-distance flight in an aeroplane; he flew not only in public, but before some officers who attempted to overtake him at the gallop. He repeatedly described his usual circuit at great altitude, frequently exceeding 40 metres. Lastly, notwithstanding the weight of his wheeled carriage, it lifted itself and me *by its own effort*, traversed a distance of 1600 metres, and completed a turn, the apparatus showing as perfect a stability as if the pilot were unaccompanied.

"'A magnificent day's work for French genius!' wrote a young officer who was overcome by enthusiasm at these experiments."

It would be useless to add a line of comment to this criticism from one of our most learned mathematicians, a criticism enunciated on October 28, 1908. Two days later Farman and Blériot substantiated his statements by completing, on the 30th and 31st of the same month, the two "first aerial voyages" from town to town. That is a distinction of which none can ever attempt to deprive them; they were the two first "tourists of the air."

It is possible by means of so exact a comparison to grasp intimately the fundamental difference between these two "schools" of aviation. We see that the American school demands *everything* of the aviator, longitudinal, as well as lateral, stability, whilst the French school assures the longitudinal stability by means of an empennage and a long leverage arm, which is an important point. The two schools may best be likened to those two machines, the monocycle and the bicycle respectively. Neither has lateral equilibrium, and the rider must secure it in the same manner upon both. But whereas he must also obtain longitudinal stability upon the monocycle, on the other hand, with the bicycle this is inherent, owing to the two points of support on the ground.

Consequently, while any one can manage a bicycle, only those expert in balancing will risk themselves upon a monocycle.

The French aeroplanes—*Blériot*, *Voisin*, *Farman*, *Antoinette*—are the bicycles of the air. Every one will be able to use them. The exploits of Latham at the Châlons camp, where, after only a few lessons, he was able to remain in the air on his *Antoinette* aeroplane for *sixty-seven minutes*, and to lift two passengers; of Farman, who flew for over an hour with two passengers; of Sommer, who made the first trip with "four up"; and of Paulhan, who sped across England, &c., demonstrate the facility and safety of their management. On the other hand, one knows the long practice, the skill that is requisite to use a *Wright*. Wilbur Wright possesses this skill to an extreme degree, but its acquisition is not open to all and sundry, no more than the balancing of a monocycle.

HELICOPTERS AND ORNITHOPTERS : THE BREGUET GYROPLANE

A word remains to be said about aviation apparatuses based upon principles other than those of the aeroplane. There are, first of all, the helicopters, or apparatus with sustaining screws. So far these apparatuses have not given decisive results. True a fairly heavy apparatus succeeded in rising from the ground on several occasions, even with the aviator; but what is difficult, and what is so far only promise, is the steady advance of the apparatus through the air. Hitherto the efforts of investigators have been confined almost exclusively to sustentation by screws. We have mentioned Colonel Renard's works upon this subject, and the hopes inspired by rather hasty interpretations of the formulæ which summed up his calculations. A few trials of direct sustentation by screws have been carried out recently, the most important being those of Engineer Léger (Monaco), M. Paul Cornu, and M. Louis Breguet. We have already spoken (p. 146) of the first of these apparatuses. Let us now say a few words about the two others, which have furnished interesting results.

We know what "screw-slip" is—the propeller revolves in the air like a screw, but the mobility of the molecules of the latter causes the apparatus to advance only a fraction of its "pitch." The difference defines the *slip*.

Until recently attempts were made to reduce the slip as much as possible by decreasing the pitch of the screw for sustaining propellers used with helicopters. This slip, however, cannot be entirely overcome. Therefore M. Cornu sought to use the slip for the horizontal propulsion of the aviation apparatus. This is the principle of his machine.

A frame carries a motor, which transmits its power through endless belts to two screws, one on the right and the other on the left, and turning in opposite directions to annul torsion efforts. These are the "sustaining" screws devised to lift the apparatus in the air. The effect of their slip produces a downward back-thrust of air, whereas their useful effort secures the sustentation of the apparatus. This backward drive of air is used for horizontal propulsion by means of inclined planes placed under the screws. These oblique surfaces transform the vertical effort of the descending air into a horizontal component which displaces the apparatus in a given direction. By inclining differently two series of these planes placed on both sides of the axis, turning and inclination may be obtained. Such is the principle of the Cornu apparatus. Plate XXXIII. shows the general details of its construction. Results therewith have been encouraging. Once the apparatus rose with its aviator on board; on a second occasion it ascended with two men, the total weight lifted being 328 kilos. It remained in the air for one minute. Propulsion, due to the horizontal effort exercised upon the

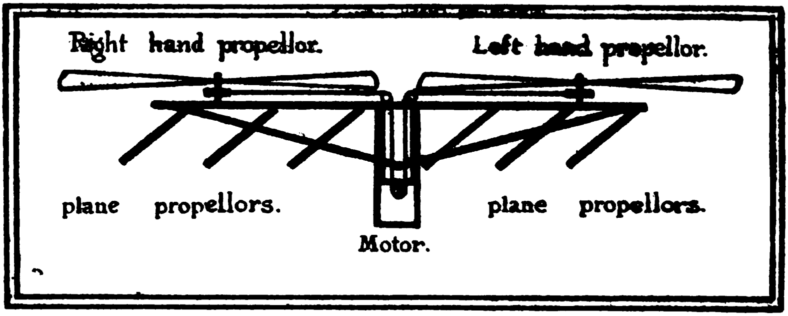


FIG. 78. The principle of the Cornu helicopter

The screws secure ascent vertically, and the resistance of the air upon the oblique plane propellers produces lateral displacement oblique planes, was weak—only 12 kilometres an hour. It may be seen from the foregoing that this helicopter is amongst the most interesting of its type, and such experiments must be encouraged, as, without a doubt, it is from this line of development that the perfect sustaining screw will be evolved. Perhaps it will be possible to associate such with the aeroplane some day.

Special mention must be made of a very interesting aviation apparatus—the *gyroplane* of Messrs. Breguet and Richet. This fulfils the combination of the aeroplane and the helicopter in a happy manner, since it comprises an association of *fixed*, with *revolving*, wings. The photograph enables their arrangement and operation to be understood very clearly.

The total surface of the revolving wings is 11 square metres each. The surface of the fixed wings is 50 square metres, which, in the event of a vertical descent, provides a total area of approximately 72 square metres to form a parachute. The oblique disposition of the screw shafts may be observed as soon as the propellers are in motion. The reaction of the air upon the fixed surfaces gives a double effort—an upholding vertical effort, and a horizontal effort serving for forward propulsion.

With aviator and petrol sufficient for one hour, the apparatus weighs 600 kilos; the "Antoinette" motor develops 40 horse-power. A balancer which can be warped, placed at the bow, and lateral small wings, ensure stability, and permit the aviator to regain such in the event of accidental inclination. A rudder at the stern of the apparatus acts as the vertical empennage. The fixed and revolving surfaces are flexible, and constructed upon very ingenious lines. They are covered partly with very thin aluminium sheets, and partly with special waterproof and non-hygrometrical paper.

The apparatus has been tested successfully at Douai, on ground purposely selected as unsuitable for the launching of ordinary aeroplanes—a beetroot field. The apparatus rose straight into the air with the greatest facility. An accident interrupted the experiments, but the results are most encouraging, and of a nature to induce the designers of the apparatus to persevere in the path they have selected.

The *ornithopter* has been studied and constructed upon feasible lines by Mr. Adh. de la Hault, a Belgian aviator. Without seeking to "fly" right away, this distinguished constructor first devoted his attention to the study, working, and efficiency of the "flapping" wings. He built a novel apparatus, showing distinctive mechanical ingenuity, which describes a movement in the form of the figure 8, according to the curve which mathematicians call "lemniscate." By means of this complex action, the author hopes to realise the dual propelling and sustaining function of a bird's wings. Mr. de la Hault's apparatus figured in the 1908 Brussels Exhibition, and the remarkable mechanical features were much admired by engineers. The inventor is now pursuing his researches, and undoubtedly important results will be obtained.

There remains but to indicate an American *ornithopter* with flapping wings, provided with Venetian blind blades, which close in descent and open in ascent. We have no data regarding the practical results achieved by this apparatus.

In concluding this history of the principal aviation apparatuses as designed up to now, we may say confidently that the aeroplane alone, so far, has furnished really practical results, and has shown in its various forms absolute superiority over the two other aviation systems. This justifies the enthusiasm it has provoked and which its continuous development is maintaining. What is necessary is to ascertain how either supporting screws or propelling surfaces can be added thereto. With the aeroplane in its present promising form, it is obvious that aviation, the "heavier than air" science, is far from having said its final word; it has barely said its first.

CHAPTER VI

EARLY DAYS OF AVIATION

FORERUNNERS AND PIONEERS : THE STRUGGLES, TRIUMPHS, AND THE VICTORS : THE MARTYRS

THE FORERUNNER : SIR GEORGE CAYLEY

Now, knowing the conditions an aviation apparatus must fulfil; realising the difficulties that are encountered in seeking to evolve, raise, and control it; glancing back to see how the traveller has arrived profitably at the end of his journey; and instructed in its handling, we shall be better able to appreciate the immense effort put forth by those who were the creators of "heavier than air" aerial locomotion.

Let us at once reassure the reader that we will not hark back to Icarus or legendary history. We will take aviation only from its modern origin; start from the time when methodical ideas were calculated sufficiently to enable investigators to proceed on serious and practical lines, instead of aimlessly groping about in the dark.

The first serious investigations relative to aviation date only from the commencement of the nineteenth century, and it was the aeroplane which arrested attention. By a curious coincidence, even as the first projected airship, that of General Meusnier, was "complete," and anticipated all the necessary equipment, so was the first aeroplane conceived "complete" and everything essential therefor indicated by its author.

This inventor, the incontestable forerunner of aviation, was an Englishman, *Sir George Cayley*, and it was in 1809 that he described his project in detail in *Nicholson's Journal*. In the course of an excellent paper presented to the Société des Ingénieurs Civils, M. Soreau recalled this date, when he remarked how sad it was to think that such a valuable invention as this had not been possible of application immediately upon its conception. Sir George Cayley's idea embodied "everything"—the wings forming an oblique sail, the empennage, the spindle forms to diminish resistance, the screw-propeller, the "explosion" motor, the calculation of the centre of thrust, and demonstration of the fact that displacement takes place towards the front. The author even described a means of securing automatic stability! Is not all that marvellous, and does it not constitute a complete specification for everything in aviation?

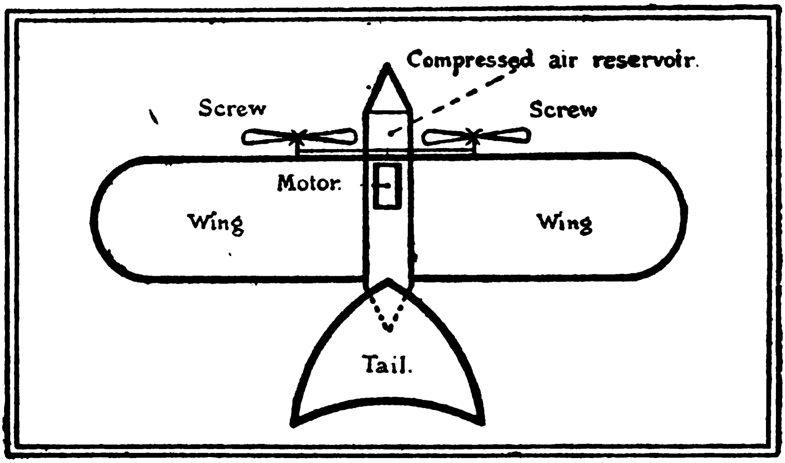


FIG. 79. Victor Tatin's aeroplane model driven by compressed air made a flight at Meudon in 1879

Thus it is necessary to inscribe the name of Sir George Cayley, in letters of gold, on the first page of the aeroplane's history. Besides, the learned Englishman did not confine himself to "drawing-paper": he built the first apparatus (without a motor) which gave him results highly promising. Then he built a second machine, this time with a motor, but unfortunately during the trials it was smashed to pieces. In 1842 another Englishman, Henson, attempted to build a model aeroplane upon this principle, but without success. One must pass on to the year 1856 to find the first experiment with apparatuses that "rose into the air" with a passenger aboard. It was nothing more than sustentation from a huge kite, hauled by a vehicle. This initial tentative effort was carried out by Le Bris, a French sailor. The first attempt to glide aerially by a "soaring plane" was made with what was really a triplane by *Wenham* in 1866. Such an apparatus was used thirty years later in the experiments of Chanute, Wright and Archdeacon. Nor must it be forgotten that towards 1860 Nadar, Ponton d'Amécourt and de la Handelle carried out their "heavier than air" campaign, and that in 1862 the first steam helicopter was built by Ponton d'Amécourt, a model, it is true, but a working model, which is preserved in the archives of the French Aerial Navigation Society. A small model of another helicopter, built by *Enrico*, which was driven by a small steam engine, and weighed 3 kilogrammes all told, lifted itself from the ground and remained in perfect equilibrium without any material contact with the earth in 1878.

The three first aeroplanes or models of aeroplanes which truly "soared" were the small apparatuses of *A. Penaud* which followed the lines of a monoplane with an empennage tail (Fig. 43), and Victor Tatin's aeroplane constructed and tested at Chalais-Meudon in 1879. The latter was driven by compressed air and its trials were absolutely convincing. Held by a cord secured to the centre of a small circular track, the machine ran round the track, stretched the cord, and rose into the air. Subsequently, in 1896, the celebrated American physicist, Professor Langley, contrived a small steam-driven aeroplane weighing 13 kilogrammes, having two pairs of wings placed, not one above the other, but one in front of the other—in "tandem." Although this aeroplane did not lift itself, it accomplished the first aerial journey by covering 1½ kilometres through the air. A second aeroplane was built some time after (in 1903). It rose into the air, but undoubtedly owing to the controlling aviator's inexperience it fell into the Potomac.

Yet investigators continued their experiments, and two names, both well known in industry, are inscribed in the golden book of aviation. One is that of Sir Hiram Maxim, the famous inventor of quick-firing guns, who up to 1890 had expended over £40,000 in the construction of a very large steam-driven aeroplane. This apparatus, notwithstanding the great achievement of its inventor in regard to the lightness of the steam engine (15 kilogrammes per horse-power), only displayed a "tendency to lift itself"; it never actually rose.

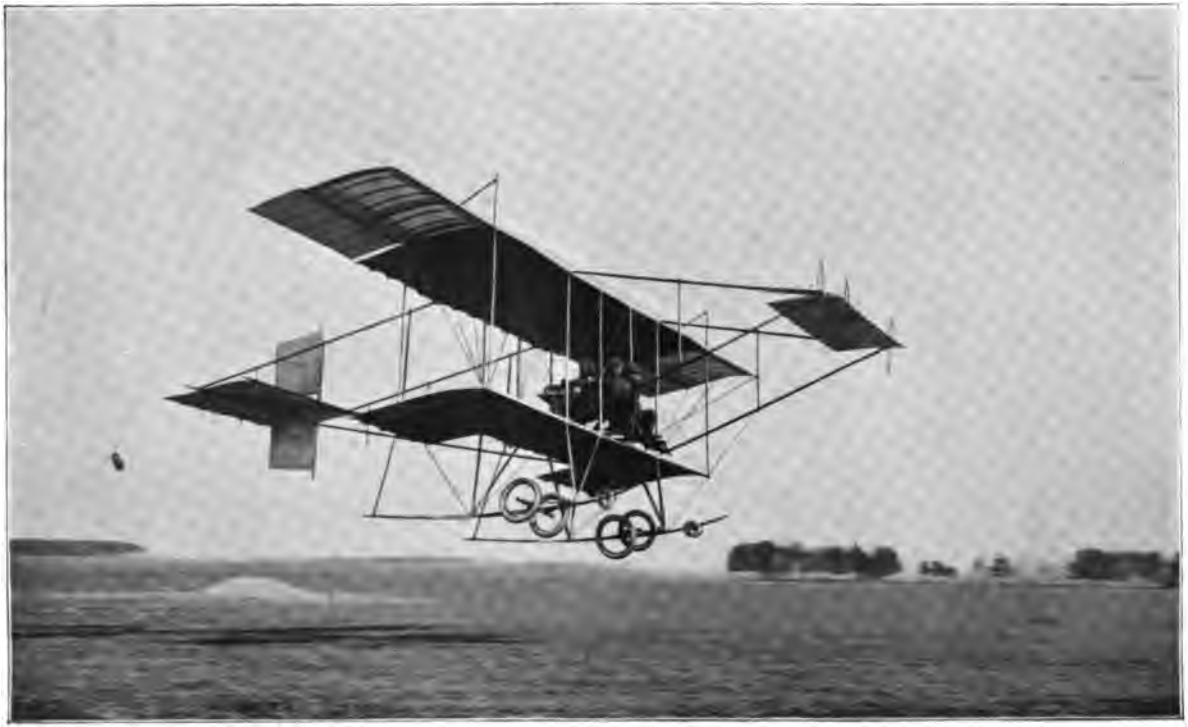
The other industrial magnate was M. Clément *Ader*, famous for his great developments in the construction of telephonic apparatus. In 1890 and 1896 he built two aeroplanes which he christened *Avion*. On both occasions the apparatuses *lifted themselves from the ground*, and in 1896 at Satory the apparatus *completed a flight of 300 metres* after leaving the ground under its own effort, before officers delegated by the Minister of War. If, therefore, the honour of having *conceived* the first aeroplane rests with an Englishman, the merit of having *constructed* the first apparatus that effectively flew, is due to a Frenchman—a glorious example of the *entente cordiale* associated with the history of human progress.

THE "HUMAN BIRDS": LILIENTHAL, CHANUTE, CAPTAIN FERBER, THE BROTHERS WRIGHT

Whilst some engineers were seeking "to break in" machines to sustain in the air, other investigators were compelled to seize the mechanism of the "soaring plane," and upon these motorless gliders, utilising only their weight and the resistance of the air, served their "bird-apprenticeship." Foremost among these persevering and daring men, must be placed the rightly renowned name of the German, *Otto Lilienthal*, who long before the Brothers Wright (they merely followed in his footsteps in their earliest attempts), accomplished some remarkable experiments in this direction, in the course of which he lost his life in his devotion to aviation science.

Lilienthal, a Berlin engineer, built veritable birds'-wings, by means of which, when fixed to his body, he sought to achieve the "soaring flight" of birds of which we spoke in a previous chapter. These wings, of which the photograph (Plate XXV.) gives a very good idea, were formed of an osier framework, covered with light, stretched fabric. Two horizontal rudders, forming a bifurcated bird's tail, were at the rear, surmounted by a large steering rudder of rounded form. Lilienthal, well poised in the centre of this framework, jumped from the top of

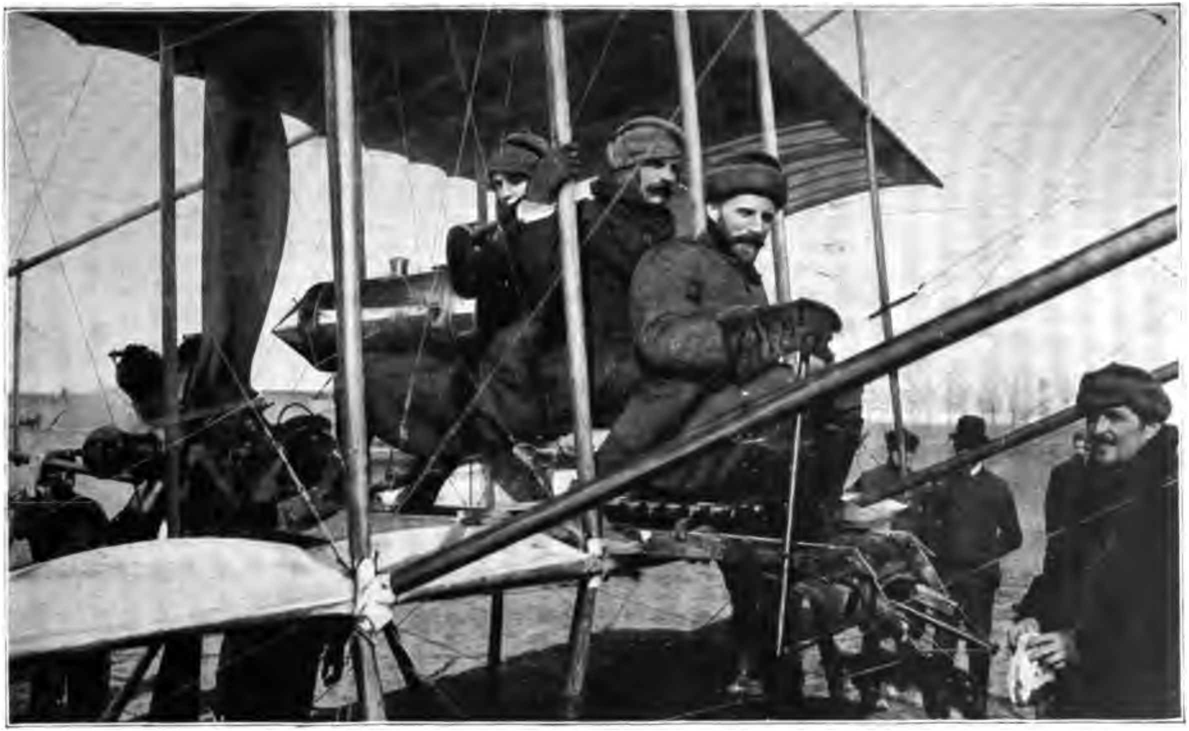
PLATE XXXIX



Photo, Rol

HENRY FARMAN, CARRYING TWO PASSENGERS, ON HIS BIPLANE CREATED RECORDS FOR DURATION AND DISTANCE OF FLIGHT

PLATE XI.



HOW PASSENGERS ARE ACCOMMODATED ON AN AEROPLANE

Photo, Rol

a low tower, against the wind. The inclination of his body and legs enabled him to shift the centre of gravity of the whole system. In this manner he carried out some remarkable flights, some of which attained 300 metres in a horizontal direction. After he had made about a thousand such Lilienthal changed the form of his "flier." Abandoning the *monoplane* he built a *biplane*, and broke his neck in a fatal fall from a height of 80 metres in 1896.

The experiments of the unfortunate German engineer were of incontestable value in demonstrating the efficiency of carrying surfaces and the possibility of realising equilibrium under the best conditions during flight. The Americans followed in his footsteps, and among the first of those who, in the United States, sought for the solution of the problem by the study of the soaring plane must be mentioned a Frenchman, long resident in New York, M. Octave Chanute, born in Paris in 1831 of French parents. Chanute, although well advanced in age, continued the experiments of Lilienthal. He emphasised the *biplane* and happily first conceived the disposition of the balancers.

In 1899 *Ferber*, captain of artillery, commenced in France a series of very beautiful experimental researches first in glides, afterwards in the conditions of equilibrium. He even tried an aeroplane fitted with a "manœuvring" motor, describing a circular movement about a fixed point to which he was mechanically connected. His work and writings place him prominently among those to whom we owe so much, and it is inspiring to see a French officer occupy a distinguished position in the ranks of these "forerunners" who planned out the path so well.

So, when, in 1900, the brothers Orville and Wilbur Wright, bicycle makers of Dayton, set out to tackle the problem they found the ground well prepared. Lilienthal had shown the way, Chanute had indicated the arrangements, and the Brothers Wright perfected them. They "strove for the point" with great judgment, skill, and, above all, an extraordinary determination to become "human birds." They commenced by carrying out numerous aerial glides with their biplane so as to secure aerial equilibrium. These glides suggested many happy modifications to them, and encouraged by the *doyen* of aviators, Octave Chanute, in 1903 they built their first motor-driven aeroplane, with which they performed several flights in a straight line. It was not until 1904 that they effected their first turn. Then they embarked upon long flights of many kilometres at an average speed of from 60 to 65 kilometres per hour. Their experiments were so wrapped in mystery that many would not believe them. Among the few persons in France who really credited the performances of these two transatlantic aviators, were Captain Ferber, M. Rodolphe Soreau, and M. Henri Letellier. In view of the military possibilities of their machine, M. Letellier even sent one of his collaborators, M. Fordyce, to America to negotiate with the two inventors for the cession of their apparatus to the French Government. These negotiations were not successful and it was not until the summer of 1908 that Wilbur Wright, at the request of a group of financiers with whom he had been in treaty, went to France. He carried out his first trials at Mans, at the camp of Auvours, upon the Hippodrome des Hunandières, where he executed numerous flights all under "experimental" conditions, but never once set out under his own effort, and made no actual voyages. Nevertheless it must be remembered that, thanks to his aviating skill, Wilbur Wright completed some flights of very long duration. Among them he succeeded in repeating the exploit of the Frenchman, Delagrange, by carrying as a passenger M. Paul Painlevé, of the Académie des Sciences, with whom he remained in the air for over an hour.

These experiments, owing to the enormous publicity extended, created an immense sensation. One had forgotten somewhat the French aviators when two of them established remarkable records, and created distinction by making the two first aerial voyages in an apparatus "heavier than the air" on October 30 and 31, 1908.

EXPLOITS OF THE FRENCH AVIATORS : SANTOS-DUMONT, VOISIN, DELAGRANGE, &c. : THE MÆCENE : HENRY DEUTSCH, E. ARCHDEACON, ARMENGAUD

The flights of the Brothers Wright were very beautiful demonstration experiments, but nevertheless the aeroplane of the Americans is not perfect. Its stability demands a constant effort on the part of the aviator, because of the suppression of the empennage tail, and for this reason the apparatus is dangerous.

French aviators worked quietly towards the solution of the problem, and to its *complete* solution. In other words they sought the perfection of a *self-starting* aeroplane, able to rise from the ground under its own effort, and after having landed to restart without either rail or pylon.

At the end of 1903, the ardours of the audacious French aeronauts were revived. That year Colonel Renard pointed out that, when the weight of the motor was brought below 5 kilogrammes per horse-power, flight by means of "heavier than air" machines was possible. The great authority, the sanguine views of the illustrious and learned officer were more than a hope; they were a guarantee for the pioneers who set out towards the conquest of the atmosphere.

Among the most prominent of distinguished ardent sportsmen was Ernest Archdeacon, who, as far back as 1904, made some experimental glides with an aeroplane among the dunes at Berck-sur-Mer. At that time what perseverance was necessary to pursue, without faltering, this struggle with the uncontrollable element! What faith in the future, not to allow one's self to be turned away by the criticisms and the more or less witty satires of the detractors who are always more numerous than the "actors"! But the latter were enthusiasts; nothing would stop them. Voisin built and tested with Archdeacon, Ferber and Santos-Dumont. The last-named sought to forge the "connecting link" between the aeroplane and the kite. He constructed a biplane which could float upon the water, and had it towed along the Seine by the *Rapière*, one of the fastest existing motor-boats. The apparatus rose, carrying the aviator, thus excelling the bold efforts of many persevering workers. The possibility of aviation was established now. Experiments in aviation also multiplied.

It is necessary—it is essential—to point out that nothing had transpired concerning the experiments of the Brothers Wright, whose existence was scarcely known. A stronger reason for being ignorant of details concerning their mysterious machines was that their authors jealously guarded themselves against prying eyes. Moreover, does not the merit of the French aviators stand unique? Not only have they done *as well*, but they have done *better*. What more can be asked?

M. Santos-Dumont was the first to succeed. The intrepid Brazilian aeronaut carried off the first prize which the generous Mæcene of aviation established in 1906. With what is this date to be compared! In 1906 not a motor-driven or self-starting aeroplane had left the ground. Thus it may be seen that he who could make a flight of *100 metres* would achieve indeed an admirable exploit. Santos-Dumont carried off "the prize for 100 metres" at Bagatelle on November 12, 1906; some time after Delagrange and L. Blériot won the prize for 200 metres by a flight of 220 metres.

Two gentlemen then appeared on the scene who by their lavish generosity have contributed greatly towards the development of aerial sport—MM. Henry Deutsch and Ernest Archdeacon. The flights so far accomplished were in a straight line; the aviators hesitatingly refrained from risking a turn. They saw the difficulties we have already pointed out. MM. Deutsch and Archdeacon offered a prize of £2000 to the first aviator who accomplished a *circular* kilometre. This prize was won by Henry Farman, at the Issy-les-Moulineaux manœuvring grounds, on January 13, 1908.

Thereafter the triumphs of this persevering aviator continued without interruption. On July 6, 1908, by remaining in the air for twenty-one minutes, he won the prize so spiritedly offered by the engineer, M. Armengaud, to the aviator who could remain aloft for a quarter of an hour.

THE TWO HISTORICAL AVIATION VOYAGES BY FARMAN (OCTOBER 30) AND BLÉRIOT (OCTOBER 31, 1908) WHO ACCOMPLISHED THE TWO FIRST "AERIAL JOURNEYS" FROM TOWN TO TOWN

However, all preceding records were completely eclipsed by the two exploits of H. Farman and L. Blériot.

Hitherto aeroplanes had simply described evolutions over race-courses or aerodromes, where the ground, purposely levelled, offered the best facilities for the ascents and descents of the French aeroplanes. These advantageous conditions were not sufficient for the American aeroplanes, because it was necessary for them to have also a pylon and launching rail. Thus the aeroplane had to demonstrate its possibilities of endurance, to show that it possessed really practical utility, and that it did not require special facilities at halting-places in its aerial passage.

MM. H. Farman and L. Blériot had the unquestioned and indisputable distinction of fulfilling this demonstration, which was anticipated by the whole world. They proposed to embark upon an actual journey from *town to town* and they succeeded.

Henry Farman left the precincts of his shed at Bouy, near the Châlons Camp, at 3.50 on October 30, 1908, and set out for Rheims. The wind was E.S.E. The aviator immediately gained a height of about 50 metres, which was necessary, owing to the stretches of tall poplars barring his path. He flew over rivers, villages, woods, &c., and, after being twenty minutes on the journey, reached Rheims, where he landed with the utmost ease in a park between the cavalry barracks and Pommery House. During this twenty minutes he covered 27 kilometres, which gave a " start to stop " speed of 79 kilometres per hour.

On the following day (October 31, 1908) Louis Blériot completed a still more sensational and perfect "journey." Leaving Toury (Eure-et-Noir) at 2.50, he steered towards Artenay (Loiret), a point situated some 14 kilometres from the starting-point. There some captive balloons had been sent up to indicate the point where he was to turn.

Flying a dozen metres above the ground, the aeroplane passed over Château-Gaillard and Dambrou, and the automobiles which were following him were speedily "scattered" along the roads. Eleven minutes after the start an ignition fault compelled him to alight. He landed without difficulty, *repaired his magneto, and set out again under his own effort,* after a descent lasting an hour and a half, to continue his journey.

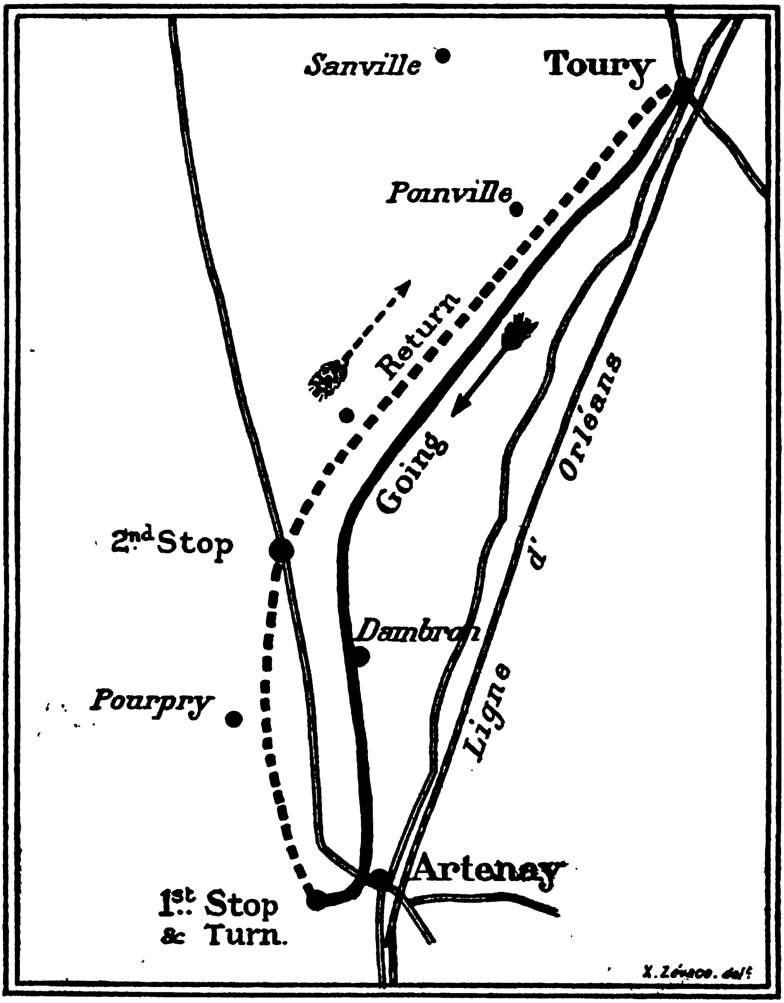


FIG. 80. The first "aerial voyage" made in a closed circuit from Toury to Artenay and back, by Louis Blériot, on October 31, 1908

Holding more to the west, he passed Pourpry, and made a second descent of some minutes at Villiers Farm, near Santilly. *He re-started a second time,* passed Pointville at five o'clock, and returned in quite a matter-of-fact manner to his starting-point, having accomplished the first "cross-country" voyage with descents. During this flight his aeroplane acted marvellously well, attaining a velocity of *85 kilometres per hour* (Fig. 81).

Thus, Louis Blériot demonstrated that the French aeroplanes mounted on wheels are complete apparatuses, truly self-starting, practical, and capable of resuming their flight when it is interrupted. He proved the services that aero-locomotion could render us, and illustrated that aviation from that time henceforth could enter into everyday practice.

Certes, one had been so persuaded, but a good practical demonstration is worth more than exhaustive arguments: *contra factum non valet argumentum.* Consequently Farman and Blériot were absolute demonstrators, and definitely opened "the Highway of the Air." It was a fair act of the Académie des Sciences to divide the Osiris prize between Blériot and Voisin, the creators of these marvellous aviation apparatuses.

THE LATEST ACHIEVEMENTS OF THE AVIATORS LATHAM, ROUGIER, COUNT LAMBERT, PAULHAN, DUBONNET, &c. : BLÉRIOT'S FLIGHT ACROSS THE CHANNEL : PAULHAN'S FLIGHT OVER ENGLAND: THE CROSSING OF THE ALPS BY CHAVEZ

In July 1909 a prize was offered for crossing the Channel by aeroplane. Latham, on an *Antoinette* monoplane, attempted to carry it off. On the first occasion he fell in mid-Channel, and was rescued by a torpedo-boat. By no means discouraged, he made another effort some time later. Leaving the French coast, he again fell into the sea when but little more than a mile (1852 metres) from the English coast. He failed, but his feat proved that the prize could be won. It was secured two days later by Blériot, who, starting from the outskirts of Calais, alighted on the cliffs of Dover.

We gave this French aviator a triumphant welcome, and his return to France assumed the character of a national event.

In April 1910 the *Daily Mail* offered a prize of £10,000 to the aviator who flew from London to Manchester within twenty-four hours, and without making more than two stops during the journey. Mounted on a Henry Farman biplane, fitted with a Gnome motor and Chauvière propeller, the French aviator Paulhan snatched victory from his rival Graham White by covering the distance—over 300 kilometres—in 4 hours 12 minutes. It is difficult to describe the reception extended to Paulhan upon his return to London. He was received with the strains of the "Marseillaise" and of "God Save the King," while his carriage was hauled along by enthusiastic admirers.

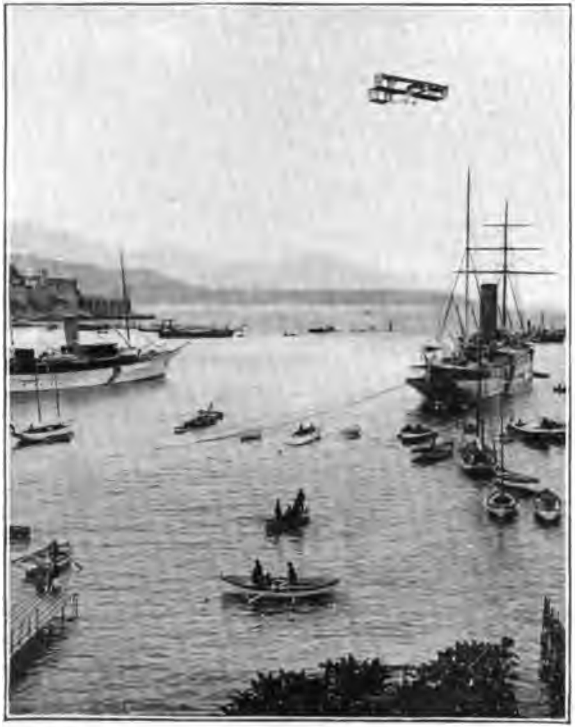
This last-named exploit never will be forgotten owing to its exceptional importance. It demonstrated conclusively that aviation was practicable, and that its entry into our daily life was no more than a matter of perfecting details. Consequently Paulhan's "journey" constitutes not only an important date in the annals of aviation, but in the history of civilisation as well.

But it is unfair not to mention the magnificent flights of other aviators. In the early days they strove to show that the aeroplane could fly just as high as the dirigible. Altitudes of 300, 400, and 600 metres were attained successively. But the finest records commenced with Latham upon a monoplane and Paulhan upon a biplane.

On January 7, 1910—the day of the funeral of Delagrange, a victim to his devotion to aviation—Hubert Latham rose into the air as if to take a sweet revenge. He left the ground at the Châlons camp at 2.30 P.M., followed a sweeping circle by Bourg and Mourmelon, described an ascending spiral, thereby gaining a greater and greater height. In thirty-two minutes he had reached an altitude of a little more than *1000 metres!* The feat was authenticated, upon descent, by a report signed by General Journée and Lieutenant Lardet. The kilometre in altitude so coveted was achieved!

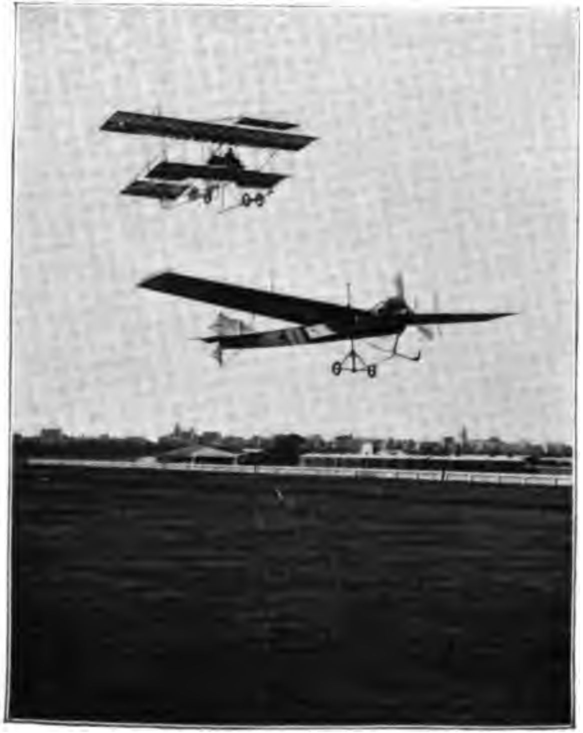
But Hubert Latham did not hold the altitude record by aeroplane for very long. On January 12—that is, five days later—Louis Paulhan, at Los Angeles (California, U.S.A.), in a flight officially measured, attained the height of 1269 metres.

PLATE XLI



Photo, Rol

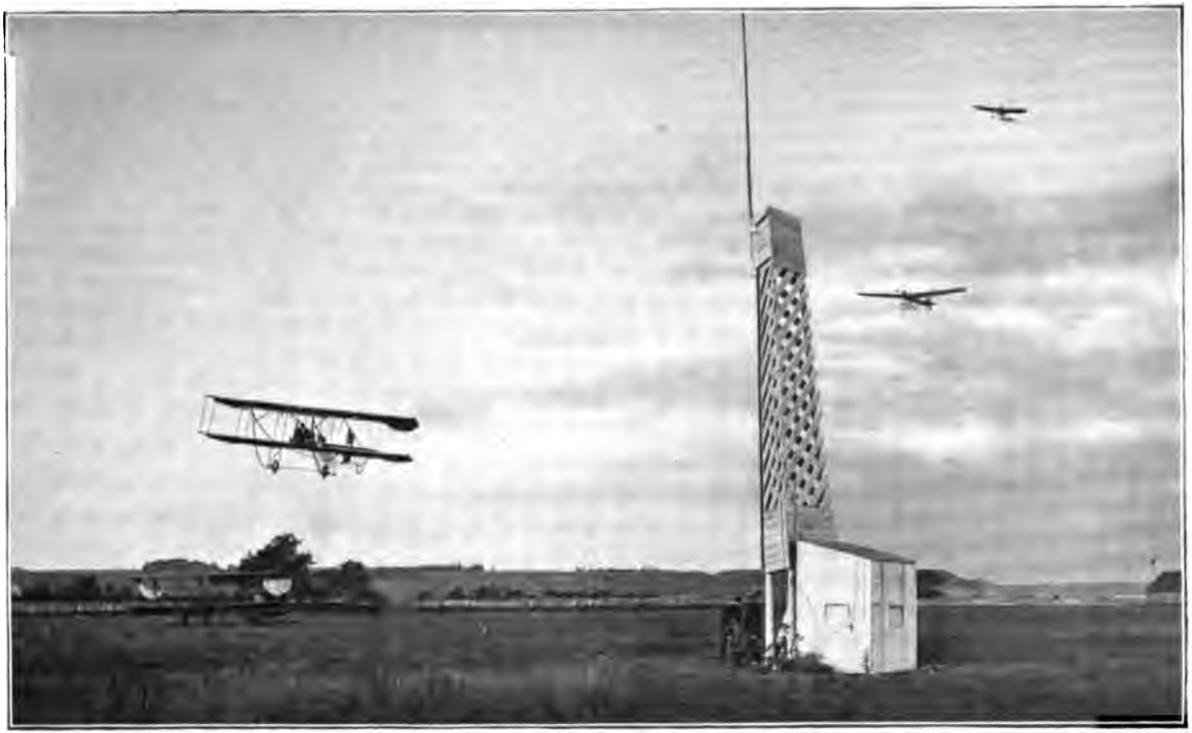
ROUGIER FLYING OVER CAP MARTIN (MONACO 1910)



Photo, Branger

LATHAM UPON HIS "ANTOINETTE" AND MARTINET UPON HIS "FARMAN"

PLATE XLII



Photo, Rol

MORANE ON A "BLÉRIOT," LATHAM AT THE WHEEL OF AN "ANTOINETTE," AND, BELOW, BOUVIER ON HIS "SOMMER" ROUNDING THE MARK

It will be seen how, in making the turn, the apparatus inclines towards the centre of the circle it describes, and how the aviator lowers the ailerons to restore the equilibrium of the aeroplane

On July 7, 1910, he reached an altitude of 1384 metres, and on July 30 the Belgian aviator Olieslœgers rose to a height of 1524 metres, which is practically the maximum altitude reached by a dirigible—the *Clément-Bayard*, under the hand of the accomplished pilot Capazza. At Blackpool on August 2, 1910, Chavez, the Peruvian, reached 1800 metres, and at Atlantic City (U.S.A.) in July the American Brookins notched 1880 metres. But the two highest altitudes reached by aeroplane are 2521 metres by Morane, and 2562 metres by Geo. Chavez. The latter aviator had the unique distinction of being the first to cross the Alps by aeroplane, on September 24, 1910, though he paid for his victory with his life. But he demonstrated by his magnificent flight from Brigue to Domodossola that current practice in flying is possible at extreme altitudes, and that the upper atmosphere is not closed to apparatus "heavier than air."

Speed and durations also have their champions, and here the name of the American Curtiss stands pre-eminent. At the same Los Angeles meeting where Paulhan set up the altitude record, Glen H. Curtiss, with *a passenger aboard*, travelled 88½ kilometres in an hour on January 11, despite his surcharge in weight! On April 8, 1910, a young Belgian aviator, Daniel Kinet, mounting a Henry Farman biplane, flew for *2¼ hours* with a passenger—this is the world's record.

Transport facilities increase day by day. It is scarcely three years ago since Delagrange, while in Italy, for the first time took a passenger with him. Later, at Auvours, Wilbur Wright repeated this feat. Then on August 28, 1909, Henry Farman, after making several flights with a passenger, flew for ten minutes with *two* passengers aboard; and finally, on March 25, 1910, he remained in the air with two passengers (three persons in all) for sixty-two minutes. But at Mouzon, in the Ardennes, on April 20, going one better, Roger Sommer, upon his ordinary biplane, and *without making any special modifications*, ascended and remained aloft for five minutes with *three* passengers (four people in all)—Mlle. Dutrieu (weighing 45 kilos.), M. Colombo (60 kilos.), and Frey (58 kilos.). Let us add that Sommer himself weighs 60 kilos., and that he carried 20 kilos. of petrol. This represents, therefore, a total weight of *243 kilos.* which was lifted into the air. This performance was of capital value, for it gave an idea of the effective "carrying capacity" of a well-constructed and capably handled aeroplane.

If, in addition to the foregoing, we bear in mind that to-day the launching facilities are so improved as to enable an aeroplane to rise after a run along the ground for 50 to 70 metres, we may see what gigantic strides have been made, even in a year, by this "heavier than air" apparatus. It was only a few years ago that it was laughed to scorn as much as it is greeted enthusiastically to-day.

Finally, it may be said that the aeroplane is no longer confined in its flights to aerodromes. Farman and Blériot made the first cross-country journeys through the air. Latham, at Berlin, during the winter of 1909, flew over a city for the first time. He journeyed from Tempelhof to Johannisthal, and passed over the capital of the German Empire. Some days later, in a graceful and daring flight, one of Wright's pupils, Count Lambert, a Russian aviator, set out from Juvisy, flew over Paris, rounded the Eiffel Tower, and returned to Juvisy, where his descent was made, to the accompaniment of an indescribable ovation. On April 23 Émile Dubonnet crossed Paris on his Tellier monoplane. Nor must be overlooked the audacious flights of Rougier at Monaco, where he flew over the sea and the "Tête du Chien"; those of Paulhan and his rival Graham White over the towns and cities of this country; the striking performances of the French aviator-officers who accomplished, *under service conditions*, the voyage Paris-London and Paris-Bordeaux, *with passengers.* Such enable us to realise that the aeroplane is commencing to fulfil anticipations. It is permissible to foreshadow the time of its entry into our everyday life, inasmuch as now we take no notice of journeys from town to town—the exceptional of a year ago has become the commonplace of to-day.

THE ENTHUSIASTIC PUBLIC MOVEMENT IN FAVOUR OF AERIAL NAVIGATION: "AVIATION MEETINGS"

From the day when Farman won the Deutsch-Archdeacon prize, aviation created an indescribable enthusiasm among all classes of the community. For a year the shops and vendors of post-cards sold nothing but photographs of aeroplanes, portraits of aviators, and illustrations of motors. The widespread publicity with which the managers of the Brothers Wright surrounded the experiments of the American aviators, helped to maintain this movement, and the numerous excursions of the dirigibles, which continually described evolutions over Paris, prolonged the absorbing interest of the people, provoked by the success of aviation.

At Auvours enormous crowds flocked from all parts to witness the Wrights' flights. At Issy-les-Moulineaux, where in the early days—the heroic times—the use of a manœuvring ground had been granted very reluctantly to the French aviators, whereas such a space was placed liberally at the disposition of the foreign aviators, thousands of the curious were always present to assist a flight or a descent, notwithstanding the early hour (from 5 to 7 A.M.) that was imposed upon French investigators. Cinematographs have reproduced and popularised the most successful flights; the annual reviews have introduced the aeroplane into their pictures extensively.

The latest achievements of Blériot, Farman, Dubonnet, Paulhan, and many other champions of the air, as well as those of the French aviation officers, Leblanc, Aubrun, Legagneux, the *Circuit de l'Est*, have infused the whole world with an indescribable enthusiasm. In the shops the up-to-date toy which commands the greatest sale, and which "rises" into the air, is the little monoplane or biplane aeroplane driven by an india-rubber elastic band.

But it was in the imagination of the young folks that aeronautical schemes were conceived. They dreamed of nothing but aviation. At college they made paper aeroplanes under the cover of their desks, to guard them against detection by their tutor; whilst the latter, studying for his science degree, on his part was occupied in calculating the elements of some flying-machine that would revolutionise the field of aerial travel!

The fair sex has taken to the new method of locomotion. Already graceful "aviatrices" are popular at the aerodromes, such as, for instance, Madame Delaroche, the first lady to handle an aeroplane unaided, and to obtain the aviator-pilot certificate, Miss Dutrieu, Miss Aboukaya, &c.

Aeronautical construction shops have sprung up on every side. Aeroplane constructors have their catalogues illustrated with aviation apparatuses, "payable after trial by the customer," whilst—sign of the times—agencies have been established to facilitate such transactions.

It has become necessary to satisfy the desires of the public who wish to see "flying" beyond the limits of the cinematograph. Consequently meetings, "aviation weeks," have been inaugurated, which, by the offer of attractive prizes, have brought together a large number of aviators. The first and most historical meeting of this description was that held at Rheims in the autumn of 1909. It was organised by the Marquis of Polignac, and it attracted visitors from all parts of the world. It served to show Europe how aviation had developed under the impulse of French genius. Since then meetings have succeeded one another without cessation—at Pau, Brescia, Heliopolis (in the early part of 1910), Nice, &c. To-day there is no city which has not had its "aviation week." The *Circuit de l'Est*, the first opportunity afforded aeroplanes to race over a measured definite course on days fixed in advance, like a race-meeting, demonstrated in August 1910 that the "heavier than air" apparatus was no longer an experimental appliance, but a vehicle of practical value.

The prizes offered at these various meetings were considerable. In order to afford an idea of their character we give a selection of the winnings of some aviators at these various "weeks":

CHAMPAGNE WEEK

RHEIMS, *August* 1909

Farman	£2400
Latham	£1946

Curtiss	£1520
Blériot	£500
Paulhan	£400

HELIOPOLIS WEEK

EGYPT, *February* 1910

Rougier	£3640
Métrot	£2400
Le Blon	£640
Balsan	£340
Reimskyck	£100

NICE WEEK

April 1910

Efimoff	£3102
Latham	£2422
Van den Born	£1088
Duray	£782
Chavez	£622

To the above must be added such a trophy as the *Daily Mail* prize of £10,000, which Paulhan won in so brilliant a manner by flying from London to Manchester. One may have cause to envy the calling of the aviator, who, if he does incur risks, has so many advantages to excite the imaginations of the young.

This movement was interpreted, some years ago in France at any rate, by the foundation of an aerial *League*, which had the happy inspiration to have resort to the knowledge of Professor Paul Painlevé.

An "Aviation Committee" has been formed in the French Senate under the presidency of M. d'Estournelles de Constant, while an Aerial Locomotion Commission acts in the Chamber of Deputies. But this enthusiastic movement is reflected especially in the redoubled efforts among societies actively concerned in the matter of aeronautics. There are the *Société française de navigation aérienne*, under the presidency of

M. Soreau, generally recognised as the oldest, since it was founded in 1872; *l'Aéro Club de France*, equally publicly appreciated, presided over by M. Cailletet, of the Académie des Sciences, the efforts of which have been so fruitful in the diffusion and development of aeronautics in all its branches; *l'Aéronautique Club*, *l'Académie Aéronautique de France*, *l'Aviation Club;* the *Stella*, an aero-club exclusively devoted to ladies; while other societies have increased appreciably the number of their members. At Brussels, *l'Aéro Club de Belgique*, ably presided over by M. Jacobs, a learned double of Mæcene, has followed the example of its French brothers, and is progressing in a remarkable manner. In Germany, England, and Italy the same activity is manifested. And in turn, special newspapers and journals have been created. Let us recall, first, the two original organs of aerial locomotion, *l'Aéronaute*, founded in 1866, and *l'Aérophile*, that remarkable paper directed by so great an authority as M. Georges Besançon. These two periodicals constitute the archives ot aerial navigation, as much for the past as for the present, and we have drawn extensively upon their files, with the requisite permission, to write this book; to their editors we extend our thanks. Around them have sprung up—*l'Aéro, la Revue aérienne, la Revue de l'Aviation, l'Avion, l'Aviation illustrée,* &c. In Belgium two excellent reviews, *La Conquête de l'Air* and *l'Aéromécanique*, have a wide circulation; and it is the same in London, Berlin, and Italy.

And all this is the result of the triumphs achieved during the past few years. What is the outlook for to-morrow? and how striking is the consciousness of mankind of the value of the great inventions which are perfected to modify in a far-reaching manner the conditions of existence and of social life!

THE MARTYRS OF AERIAL NAVIGATION : DIRIGIBLE CATASTROPHES : AEROPLANE DISASTERS

If aerial navigation counts its victors—alas! it numbers also its victims. Every great development in civilisation has milestones of mournful significance, and the history of discovery is often written in blood. It seems as if Nature, jealous of the inviolability of her secrets, wreaks revenge upon those so audacious as to seek to reveal them, and parries the efforts of those who attempt to unravel the mystery of her laws!

The conquest of the air, like all other conquests, has its battlefields strewn with the remains of its heroes. In its two forms it has already a long martyrology, and we will recall briefly the foremost disasters which have befallen aeronautics and aviation. We will omit accidents to spherical balloons; they are legion, and in recent times, in Germany particularly, they have increased in an impressively tragic manner.

The two greatest catastrophes to dirigibles were those of the German vessels the *Deutschland* and the *Schwartz*.

In 1896 the aeronaut Wœlfert built a balloon 28 metres long by 8·5 metres diameter, and of 800 cubic metres capacity. Two propellers, wrought in aluminium, of 2·5 metres diameter, were driven by an 8 horse-power Daimler petrol motor. The experiments were continued without success, and on June 14, 1897, the airship exploded, owing to the gas being in too close proximity to the motor, and becoming ignited, it fell to the ground, and the two aeronauts were mutilated terribly.

In 1897 an aluminium balloon, built on the rigid principle by the German aeronaut Schwartz, came to a similar end, but the aeronaut had the opportunity to save himself, though he was severely wounded in the ordeal.

Coming to the year 1902, we find two terrible calamities which happened in Paris to two airships, *Pax* and *Bradsky*, the first built by the Brazilian Severo d'Albuquerque, the second by the German engineer Bradsky.

The *Pax* was a fusiform balloon, symmetrical, with too slight an elongation, built up of a rigid frame to which were fixed the shafts of the two propellers, which revolved upon the axis of the envelope. Severo suppressed the ballonnets in the balloon, and the explosion motors were set scarcely 2·5 metres away from the envelope!

On May 12, 1902, the balloon, being released, ascended very rapidly; the stern screw refused to act; the disabled vessel tilted; a jet of flame was observed at the top of the car, there was an explosion, and the whole apparatus tumbled to the ground. The body of the unfortunate Severo and his luckless mechanician were found masses of bleeding pulp. This disaster, which occurred in Paris, caused a profound sensation.

Four months later, on October 13, 1902, the German aeronaut Bradsky ascended in a semi-rigid airship of cylindrical shape, terminating in a point at the prow and in a hemisphere at the stern. Here again *there was no ballonnet*, and the suspension was simply of the parallel type. This was the cause of the disaster. At a certain moment the aeronauts attempted a sharp turn. This set up a torsion in the suspension. The absence of the ballonnet caused the gas, a quantity of which had escaped during ascent, to rush towards the prow. The balloon reared up, and the suspension, essentially deformable, was unable to carry the weight equally. That to the front had to carry the weight of the car, motor, and passengers. It collapsed, and the two unfortunate aeronauts were thrown to the ground, where their bodies were literally buried from the force of the fall!

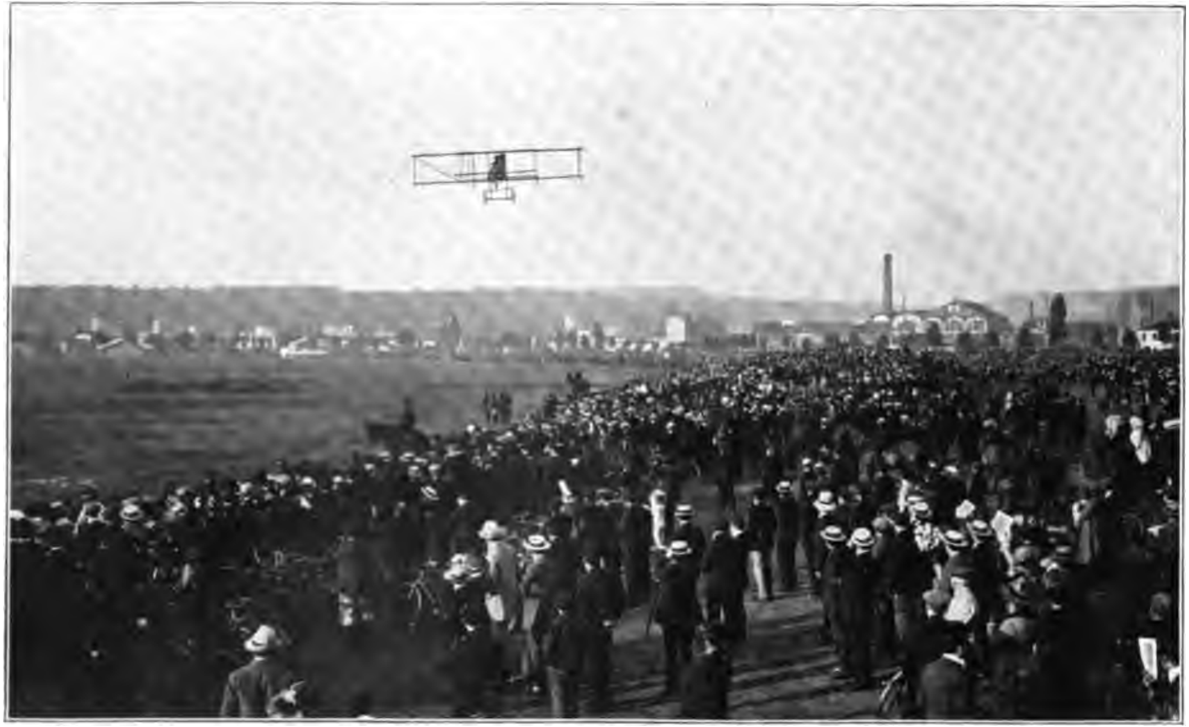
French aeronauts had been spared up to this time. There was the loss of the *Patrie*, carried away by the gale, but that was a material loss purely.

In the month of November 1909 occurred one of the most terrible catastrophes it is possible to conceive—the disaster to the French military dirigible *République*, carrying Captain Maréchal, Lieutenant Chauré, and Adjutants Réau and Vincenot.

The *République* had returned from the manœuvres, and had regained Chalais-Meudon by the aerial highway. Some automobiles followed the airship. Suddenly a kind of detonation was heard, and the dirigible crashed to the ground with the four officers aboard. The cause of the accident was novel. One of the blades of the propeller, torn loose by centrifugal force, struck against the envelope, tearing a large rent, through which the gas rushed. The balloon fell like a stone, and struck the ground with terrific force. This fearful calamity drew attention to the use of wood for propellers.

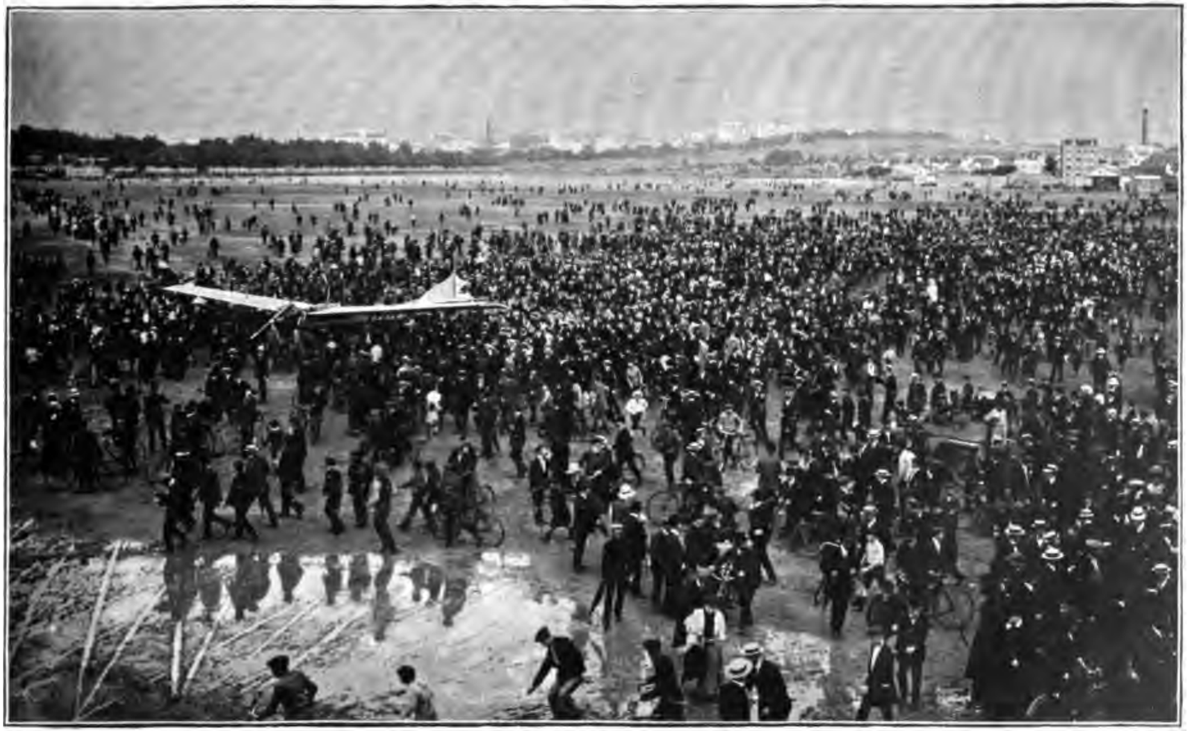
This national disaster created widespread consternation. A subscription opened by M. Hébrard, the director of *Le*

PLATE XLIII



A START: LINDPAINTER LEAVING ISSY-LES-MOULINEAUX FOR THE "CIRCUIT DE L'EST" *Photo, Branger*

PLATE XLIV



A DESCENT : THE CROWD RUSHING TOWARDS LATHAM'S AEROPLANE UPON ALIGHTING *Photo, Branger*

Temps, was overwhelmed with signatures. In a few days a large sum had been obtained, which permitted, owing to the patriotic sacrifices made by the *Astra*, *Zodiac*, *Wright*, *Blériot*, *Henri* and *Maurice Farman* companies, to offer for the national defence an aerial cruiser of 8000 cubic metres, another of 2000 cubic metres, and four two-seated military aeroplanes, as a substitute for the lost unit.

In Germany accidents to dirigibles have been numerous. Five out of six *Zeppelins* have been destroyed by mishaps at landing, happily without a death-roll. But in the month of July last the dirigible *Ersbslöh* had a tragic fall and killed five people.

The list of victims in aviation, too, is long. The first name inscribed upon this sad albeit glorious scroll of honour is that of the German Otto Lilienthal, who carried out most remarkable experiments in gliding. Lilienthal effected his aerial "glides" with an apparatus of supporting wings, but without a motor. He had made hundreds of these glides with complete success, when, in the course of his last flight, the apparatus was capsized by a current of air, he was thrown to the ground, and had his neck broken by the fall.

Since the advent of the motor-driven aeroplane—that is to say, since 1908—many aviators have paid for their aerial skill with their lives.

First, in the United States, the American lieutenant Selfridge was killed by a falling aeroplane, in which he had ascended as a passenger with Orville Wright, one of the Wright Brothers. The latter escaped with an arm and leg broken. This occurred in August 1908.

On September 7, 1909, at the Juvisy aerodrome, the aviator Léfevre had an unfortunate fall and met his death.

On September 22, near Boulogne, Captain Ferber, of the French artillery, one of the aviation pioneers, and one who, as much by his theory as his practice, accomplished a great deal in the development of the new means of locomotion, was killed in an inconceivable accident. He had not risen into the air; his apparatus was running along the ground, which it had not yet left. It was at the moment of "launching." Suddenly the apparatus overturned, fell to the ground, breaking the neck of the unlucky officer by its weight.

At Nice, on December 6, 1909, the aviator Fernandez, piloting an aeroplane which he had devised and built, fell and was killed.

Delagrange, one of the first champions of the aeroplane in France, who mounted the first Voisin machines, and who was the first to carry a passenger into the air, was killed at Croix d'Hins on January 4, 1910. He was on a *Blériot*, and finding the power of the motor to be inadequate, he substituted another engine of twice the power. In so doing did he alter the stability conditions of his apparatus? At all events the unfortunate aviator had a fatal fall.

At St. Sebastian, towards the end of March 1910, Le Blon fell vertically from a height of some 50 metres into the sea, and was killed instantly! Roble was killed at Breslau on July 18, 1910. Wachter met his end at Rheims on July 13. Rolls, who made a brilliant round trip across the Channel, was thrown to the ground at Bournemouth on July 12, and was likewise killed. Kinet, a Belgian aviator, after some magnificent triumphs, met his death at Liège on July 15, 1910, and on August 3 his cousin Daniel Kinet was killed, whilst on the same day Walden had a fatal fall at Minneola (Long Island, U.S.A.). On August 20 the Italian lieutenant Pasquo Vivaldi fell and was killed instantly; on September 20 Poillot succumbed from serious injuries after a terrible fall at Chartres, and on September 28 George Chavez, the conqueror of the Alps, and the first to gain the glory of flying over that formidable barrier, fell at Domodossola after having crossed the peak of the Simplon. He had gained altitudes of over 2000 metres without incident, to be killed during descent by a fall from a height of *ten metres!*

Such is the fatal list! It is a long one already—sixteen aeronauts and sixteen aviators! All honour to the memory of those heroes whose lives have been the ransom of progress.

CHAPTER VII

THE FUTURE OF AERIAL NAVIGATION

AERONAUTICS AND AVIATION : APPLICATIONS TO WAR, CIVIL LIFE, AND SCIENTIFIC INVESTIGATIONS : ECONOMIC IMPORTANCE OF AERO-LOCOMOTION

DIRIGIBLES OR AEROPLANES?

IT now only remains for us to ascertain what is the future of this aerial locomotion, which at present is so full of promise and has developed with a rapidity never before witnessed in the evolution of any other invention.

And, above all, it is necessary to examine individually the possible applications of the two forms of aerial locomotion, and the two types of atmospheric vehicles—dirigible balloons and aeroplanes. To which shall we give the preference, and what is the future of each?

If one were to be guided only by public enthusiasm, a trifle "packed," and so strenuous in exaggerating the merits of an invention when it "succeeds," as it is often slow to recognise it in its infancy, then aeroplanes, the last to come into popular favour, would be the only machines capable of widespread application. Scientific writers in the Press have submitted them already to all kinds of work, and they hasten to anticipate all the services which they must fulfil in the very near future, whilst they cannot defend themselves against a shade of disdain for the large airships which we saw perfected "yesterday" in the eagerness for that of "to-day."

It is necessary to allay this premature enthusiasm a trifle, as it is prone to be overdone again. It is essential to avoid, in the desire to advance too quickly, those galling experiences that occurred with motor-boats when the fanatics hailed them as the torpedo-boats of the future. The ridiculous venture upon the transmediterranean race, which a little consideration would have avoided, and in the course of which all the boats participating, except one, were lost, must serve as a lesson and give food for thought to those organisers of too premature applications.

Let us say at once that the future is immense, so immense that it is impossible to set it out in detail. But progress will be by evolution, and all that one can do actually is to indicate the broad lines.

In the first place there must be no exclusion of either of the two systems, balloons or aeroplanes: both have their *raison d'être* because they correspond to different requirements.

When it is necessary to travel very rapidly, when, above all, progressive development has assured the perfect security of aviation apparatus, one will have recourse to the aeroplane. Without doubt we shall see "aeroplane liners" of large dimensions, carrying numerous passengers, securing sustentation with nothing but their enormous speeds. But these velocities would be attended with real dangers in case of landing, or, above all, a "mishap to the machine," because, if the apparatus sustains itself by high speed, it would not have sufficient supporting surface to keep soaring without the motor. Perhaps for this reason aeroplane liners will be reserved even for transatlantic passages, as the "hull" with which they necessarily must be equipped would render landing less dangerous upon the water. Transatlantic journeys would be made at speeds exceeding 200 kilometres per hour; that is to say, *one could travel from Europe to the United States in a single day!*

But when this speed is unnecessary, it appears scarcely possible to disclaim the envelope charged with light gas, this "bladder," as it is called disdainfully by some aviators, because, if it travels at less speed, nevertheless it has the advantage of sustaining the aerial navigator in the atmosphere without the need of mechanical energy. Consequently it assures safety, and should the motor of an airship break down one would be always master of the situation, or able to continue the journey "before the wind," if the latter were in the right direction; or to land, which with a capable aeronaut would be possible always without very great risk, if one carefully excludes the use of rigid airships, all of which have finished their careers in disaster at landing, because of difficulty in handling and the impossibility of deflating them.

Moreover, an airship can carry many more passengers. It can convey them in greater comfort. When it will have attained its independent speed of 60 or 70, instead or 40 or 45, kilometres per hour, it will be able to set out practically at any time. Lastly, it can "stop" at any determined point in the aerial ocean, which the aeroplane, tributary to an indispensable sustaining speed, cannot do. Also I do not deceive myself in stating that its career is far from ended. It has no more than begun, and its development will be contemporaneous with that of the aeroplane. Let us now examine some of its applications to aerial navigation, and we will see then which is the type of locomotion best adapted to each case.

MILITARY APPLICATIONS

The perpetual tendency among nations to threaten to destroy one another by the most perfected means has resulted, first and foremost, in the application of aerial navigation to warfare.

We all know how completely France secured an advantage over all other countries by the possession of a military dirigible, *La France*, in 1885, whereas no other nation had one at its command. During the last few years the successive appearances of the *Lebaudy*, *La Patrie*, *Ville de Paris*, the *République*, the *Bayard-Clément*, and the *Zodiac* (I omit all but the best) have shown Europe that France has an "aerial navy" in being, available for the defence of her frontiers. We have pointed out also the progress Germany has made in regard to dirigible balloons, and what an aerial fleet she possesses with the several *Gross*, and especially with the *Parseval* vessels. On the other hand, the *Zeppelins* have given nothing but disappointment, whereas the French military aeroplanes have surpassed the fondest hopes they fostered at their *début*.

What type of aerial vessel will serve the needs of warfare best? The airship or aeroplane? As "combatants" or "scouts"?

I fear, after what I have heard from officers who are more competent on this subject than I, that as a combatant the airship will not be used often. Aerial battles do not appear imminent because the installation of any artillery whatever on board dirigible balloons would be extremely inconvenient; with regard to aeroplanes, their requisite high speed, and the impossiblity of "pulling up" practically prevent the use of cannon except of small calibre.

There is one good use for the airship in war: that is to drop melinite shells (or some other still more devastating explosive that may be invented) from a height into a fortified area or a besieged fort. Here we are in the realm of the possible, and this utilisation of the airship is not chimerical. It is only requisite to consider if the "result" would be very advantageous.

But experience can offer testimony on this point. In the United States it was proved with striking success under particularly difficult conditions, especially in connection with aeroplanes. Such, therefore, opens up a certain sphere of utility in combat. France, who, through her aviators, has resumed the lead among the nations in the conquest of the air, now has a military superiority as incontestable as the existence of her aeroplanes, and accomplished aviation officers who, at the "Circuit de l'Est" and at the Picardy grand manœuvres, excited admiration on all sides.

Moreover it may be pointed out that aerial vessels have little cause to fear hostile projectiles—airships because of the altitude at which they are able to float, and aeroplanes on account of the heights they can attain, and chiefly owing to their speed. During the siege of Paris in 1871, only one balloon was captured by the German troops; then the pilot who controlled it was but little experienced in aerostation.

Pausing to consider the possibility of an "aerial combat" between isolated units, it is certain that if two hostile aerial vessels met in the air they would seek to destroy one another. If they were two aeroplanes, and unless the fire from a mitrailleuse of one put the motor of the other out of action, or rendered the aviators *hors de combat*, they would be unable to withstand the collision; then there would be no conqueror, no conquest; there would be only two simultaneous catastrophes.

Would dirigibles, always cumbersome and relatively slow, much dread the pursuing speedy aeroplanes? Possibly not, because the aeronaut, when the aviator chased him in his speedy aerial skiff, would avail himself of a resource the efficiency of which is certain: he would *rise* by throwing out ballast. He would fly up in a vertical line, that is to say, would ascend very rapidly, whilst the aviator could rise only obliquely, and then in a slight slope, thereby executing zigzags, in a word, "vertically tacking." We have seen that Latham required forty-two minutes to rise 1000 metres at the Châlons camp. Lastly, whilst making its vertical tack to come up with the airship, the latter, more stable and able to carry, if not guns, at least a quick-firing weapon, or in any case grenades, would have ample time to riddle its aggressor, and much more easily than it could by firing upwards, all the more so, because the artificial bird would offer to the fire of the airships the large target of its supporting wings.

Meantime, however, the aspect of this question has changed, inasmuch as aeroplanes do not fly near the ground as they did a year ago, but now rise to extreme altitudes—in fact, to much greater heights than dirigibles. The height record of the latter type is 1550 metres (Capazza on board the *Bayard-Clément*), whilst aviators have attained and exceeded 2500 metres (Morane 2521 and Chavez 2562 metres respectively). The military value of aeroplanes, consequently, is increased from the fact that they can rise very high, and thus render themselves almost invisible to the enemy's artillery.

To sum up, I believe, therefore, that aerial vessels will be poor combatants between themselves. On the other hand, they will be useful scouts, and this will comprise their principal *rôle* in the time of war. Dirigibles, being able to carry instruments of precision capable of stopping to take a photograph or to make telemetric measurements, will be extremely valuable to the chief of an army who has them at his disposal; but aeroplanes, owing to their great speed, will be the instruments *par excellence* for rapid reconnaissances, for "raids" carried out over great distances; moreover, their capability of returning very speedily to recount what they have seen will render them still more indispensable than their "larger brothers" to the general of the future war. The Picardy manœuvres proved the invaluable services they can render to a commander-in-chief, and now that two officers can be stationed on board, a *pilot* and an *observer*, nothing can escape their rapid and positive investigation. For communication with besieged positions the aerial vessels will be unrivalled, and no longer will it be possible to isolate a fortress completely, what with wireless telegraphy and a fleet of airships, or a flotilla of aeroplanes.

With regard to uses in naval warfare, without a doubt these will be numerous. A cruiser can always have on board one or more aeroplanes; it has even the mechanical energy necessary to launch them. It can consequently send one into the air to sweep the horizon, and a hostile fleet could not conceal itself easily. Moreover, aeroplanes will be able to drop shells upon the bridges of an enemy's vessels, and it will become necessary in the construction of warships to protect this vital point from aerial attack. Undoubtedly the number of submarines will not be increased, since aeroplanes peering vertically into the waters of the ocean will perceive the torpedoes and submarines at a very great depth, whereas from the surface of the sea they could not be seen at all, owing to the obliquity of the visual rays coming from less distant points.

Will battles then be decided solely under the waters? Mystery and horror! Let us hope that these events will never come to pass.

APPLICATIONS TO CIVIL LIFE

What will be the "civil" applications of locomotion in the air? Evidently they will be numerous and varied, and it will be possible to travel either by "public service" or by private vehicles.

Undoubtedly the latter will come first into vogue. Private airships and aeroplanes will for a long time yet be vehicles *de luxe*, I may even say of great luxury, and only those privileged by Fortune, or those who wish to appear so, will be able to make avail of their use. But did we not see the same development in regard to the automobile? Will not the desire to appear, like "our friends," in a dizzy aeroplane, turn society upside down? without speaking of the fascinations of the "special costume" which the enterprise of our great dressmakers will not fail to bring out at the happy moment, and to charge for accordingly! It cannot be denied that speed has an irresistible attraction; it produces peculiar sensations, a veritable intoxication, and to taste these sensations combined with a decrease in the time occupied on a voyage will be one of the next forms of refined luxury. Besides, does not the reduction in the length of a journey increase the available time for other things, and therefore does it not, in an indirect manner, lengthen the span of life?

Among these vehicles *de luxe* aeroplanes will be the "racers": they will travel rapidly; will be able to carry two, three, or more persons. They will displace the high-speed automobile in which fanatics hurtle along at some 80 kilometres per hour; only in the air it will be "some 200 kilometres per hour." Those who are content to travel quietly and in company, and who are possessed of the "wherewithal," will favour dirigibles. Before long these will travel at 60 or 70 kilometres per hour. Certainly it is highly enjoyable to have an extensive uninterrupted view, and without having to stop on the way. Let us point out, moreover, that if by a head wind the speed of the wind curtails that of the balloon, on the other hand, when the wind is following, the two speeds have to be combined; and in choosing his wind—that is to say, the day for his trip, which is possible to those of independent means—one will make "some 100 kilometres per hour" in an airship, with the additional advantage of comfort obtainable with this "travelling coach" of the air. Then, without doubt, numerous sheds—"hostelries for balloons"—will be distributed along the great highways, and one will be able to stop *en route*, as is now possible on motor trips. So far as "public transport by airship" is concerned, this stage has not been reached yet. The unfortunate efforts in this direction by the *Deutschland*, the last *Zeppelin* to be destroyed, whereby a series of regular journeys was inaugurated ambitiously, and in the course of which a dozen travellers almost met their deaths, shows us that this application is still premature.

Let us remark, though, that for some time yet the greater bulk of the population will have to go on foot, by motor, boat, or railway. The high aerial speeds will be a luxury or sport. The conveyance of merchandise will be always by land or water. Such will be accelerated, but I do not think that for many, many years one will consider despatching goods over the aerial highway.

And yet the public authorities of the different European nations are engrossed in this great problem. Aerial navigation in effect eliminates frontiers. If ever it assumes sufficient extension to permit of the transport of merchandise the days of the "customs" and their enormous revenues are numbered.

As a matter of fact, was not the first *International Diplomatic Aerial Navigation Conference*, held at the French Foreign Office in Paris on May 18, 1910, called to discuss and control this question of commercial transport over the aerial highway, as much as questions of military import? All the European Powers were represented, and the author of this volume had the honour to be one of the plenipotentiaries.

The work of this conference was of such importance that it was not concluded at the time this book was published, and the international code in regard to the atmosphere is not promulgated yet.

Nevertheless, there is one phase of transport which will use the highway of the air, and perhaps more so than we anticipate. This is the "Post Office" for the conveyance of correspondence. I believe that before long "mail" will be sent aerially, and for this aeroplanes will be vastly superior to balloons. Being able to set out at any time, travelling at enormous speeds, they will carry letters and valuables. It will be easy to despatch them, one after the other, in all directions. Thus we shall have "hat-bands" for "aeroplane messengers," who will go direct from city to city every hour, or even more often. The only interruptions to such service will be on days of heavy storms. Then it will be necessary to trust the messenger to express trains, which will travel at far greater speeds than now. Even then distant points will complain bitterly of intolerable delay.

Undoubtedly the appearance upon the scene of aerial vehicles will modify profoundly the conditions of our existence, but it is not necessary to count upon this change coming too quickly. It will be some time before we see "aero-taxis," and the transit in towns will be maintained for many years to come by terrestrial vehicles. But it is certain that some day architects will feel compelled to cater for the aerial vehicle with elevated mooring-stations. Roofs will disappear in favour of flat terraces suited to launching and landing. Probably, however, departure will not entail more than a short running start. Such will be made *in situ*, because the flying apparatus will be, without a doubt, a combination of the helicopter and the aeroplane, an association which will assure security in the descent in confined areas and at a very great speed. Perhaps upon these flat roofs of large hotels we may even see sheds for airships! Certain it is that the "future city" will not have quite the same appearance that it possesses to-day. Wealthy residents will always turn their ambition towards the clearer, healthier, and less congested air.

SCIENTIFIC APPLICATIONS : EXPLORATION OF UNKNOWN COUNTRIES

One of the first applications of the new locomotion will be of a scientific nature, and more especially of a geographical character. The facility in moving above all the obstacles with which the surface of the earth bristles renders it eminently suited to the exploration of unknown continents, to traverse which no means of communication exist.

One knows how difficult and dangerous is the exploration of the mysterious countries, such as those of Africa, the centre of Asia, and Central South America, whilst the torrid climate, the dense vegetation forming impenetrable obstacles, dangerous animals and hostile natives, seem to league against the explorer sufficiently bold to venture into those territories where the foot of a European has never trodden.

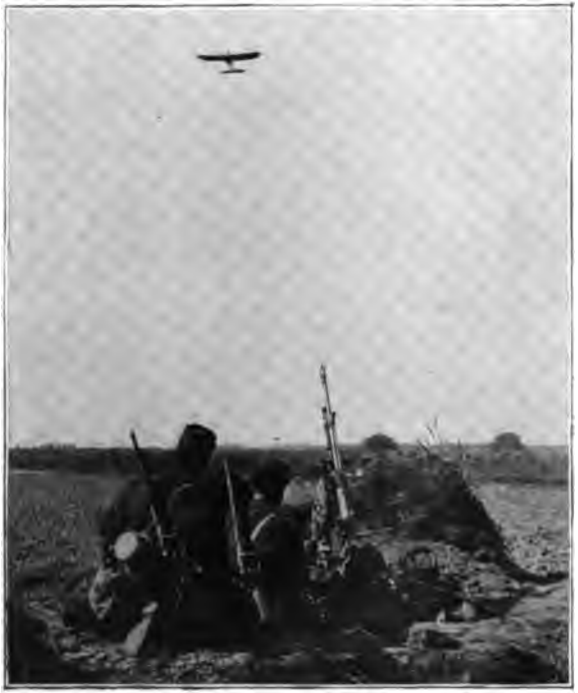
Also, what blanks exist still upon the maps of Africa, Asia, Australia, South America, and the Polar regions, Arctic and Antarctic? How slowly, in fact, are geographical discoveries effected when it is necessary to explore the details of our planet by "crawling," so to speak, over its surface! When the explorer advances through the torrid equatorial regions, when he must toil through the bush, it is as much as he can cover from 5 to 20 kilometres per day. This is the average advance of an exploring expedition. If a passage must be cut through the dense primeval forest by hatchet and axe the advance is slower still. In exploring the glacial lands of the Poles, the "icefields" of Greenland, Spitzbergen, or of the Antarctic, it is not always in kilometres that the distance between the daily halting-points is figured. Furthermore, the privations and dangers are proportional to the road traversed each day.

What is the data which the geographical traveller secures in the face of such innumerable perils? Does he bring back the complete map of the country he has penetrated at the risk of his life? No, unfortunately, because in order to prepare a complete survey of a region it is necessary to stay there a long time, and to travel in all directions. More often than not the explorer shows merely his itinerary, that is to say, only the country "fringing" the path which he followed. Certainly he will record what he sees to the right or left of this route, will indicate the hills and mountains which he has perceived on one side or the other, with their distances and heights, estimated according to "bearings." But they will only widen his "fringe" slightly without giving a general map. Moreover, the regions described in this manner will be rather more indicated than charted with essential geographical precision.

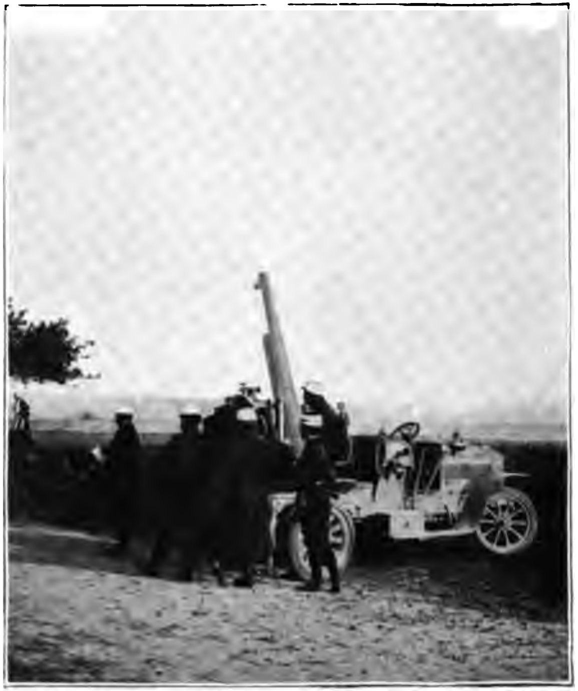
In reflecting upon these difficulties one can understand the existence of the "white spaces" in our atlas. It is marvellous that man has been able to gain such actual knowledge of the Earth in face of the passive hostility of an unknown country.

All this time, however, although we have been powerless to learn the details of the surface of our own planet, astronomers have succeeded in gathering all the details of the surface of the sky, to enumerate up to a very extended limit the brilliant stars which are sprinkled above us—briefly, they have made *a map of the heavens.*

PLATE XLV



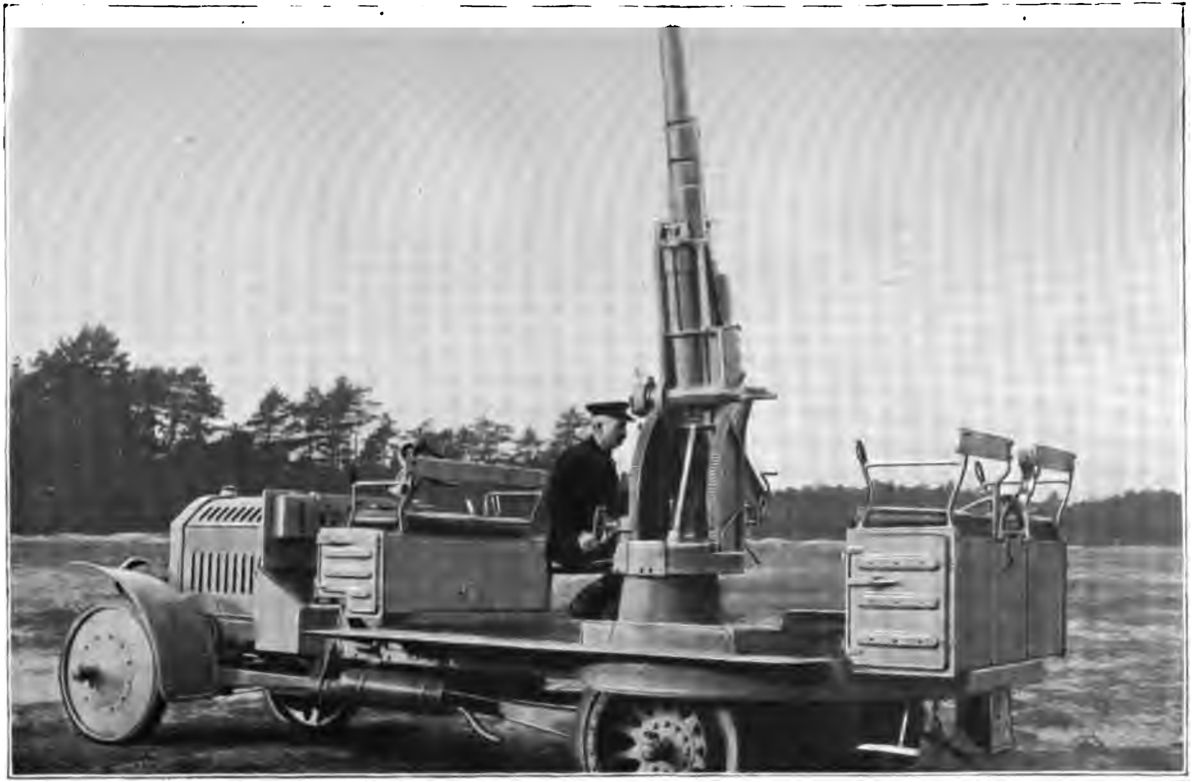
FRENCH MITRAILLEUSE, SHOWING SOLDIER TRAINING WEAPON UPON AEROPLANE



Photos, Branger

FRENCH GUN FOR USE AGAINST AERIAL CRAFT AT THE PICARDY MANŒUVRES

PLATE XLVI



THE GERMAN MILITARY AUTOMOBILE GUN BUILT BY KRUPP FOR FIGHTING AERIAL CRAFT *Photo, Branger*

They have evolved it, moreover, through a unanimous understanding among the civilised nations; they have prepared it by a surveying method which furnishes indisputable testimony—photography. The photographic plate, as was said happily by Janssen, is the "retina of the savant," but a retina which retains the impressions it receives.

Hitherto, certainly, it has been impossible or, at the very least, difficult to apply photographic processes to the representation of terrestrial surfaces in the same manner as in the preparation of the map of the heavens. In short, one had no means of "seeing the earth from above." The balloon, and captive at that, was the sole method available, and it was scarcely able to provide more than "local" views of the country beneath. Then, to obtain sufficiently numerous photographs it would be necessary to tow a captive balloon across the continent to be explored, and consequently to transport it, and its accessories, by means of a caravan. Up to now this difficulty has never been overcome.

Now, on the other hand, the dirigible balloon furnishes us with the solution so much desired, and I believe that it will fulfil it in a complete manner, thanks to the addition of topographical photography in the form so excellently and so precisely devised by Colonel Laussédat about 1852.

Let it be pointed out at once that taking only the road traversed, and even if it were kept within certain limits, the dirigible aeronaut-explorer, by vertically photographing the earth above which he manœuvred, would be able to obtain a *route survey* of a superior character to that which explorers travelling over the surface of the ground would be able to evolve. Indeed if, for example, he stood at a height of 1000 metres while photographing the earth beneath with an apparatus of which the wide-angle lens had a "field" of 90 degrees of angle, and a focal length of 20 centimetres, he would obtain a photograph which would be a topographical map on the scale of $\frac{1}{5000}$. But this map would be both exact and complete. It would be possible to obtain numerous photographs, and by placing them side by side one would have the detailed and correct topography of the route followed by the airship. Furthermore, as the latter would travel at 58 kilometres per hour, the explorer could take more maps in one hour than the ordinary explorer could make in three days, and it would be done without danger, without fatigue, safe from the attacks of natives, and protected above all from the onslaughts of poisonous insects, from marshy miasmæ, which are the greatest enemies against which explorers have to contend. An airship of to-day (as many dirigibles have demonstrated) can travel for 38 hours without descent. Therefore it would be possible to make an outward journey for 19 hours, allowing 19 hours for the return trip, anchor for the night, and in this manner explore the country within a radius of a circle of 1000 kilometres, which would take a traveller from 40 to 50 days to pass over.

But, notwithstanding the already very marked superiority of an aerial voyage from the point of security, speed, and the data obtainable, the point arises as to whether the results would justify the despatch of a dirigible to an accessible point of the continent which it is desired to study. However, then one can and must rely more and rather upon the collaboration of the dirigible and the camera.

Let us state at once that the dirigible will be improved greatly within a very short time; its present speed of 50 will be increased to 60 kilometres per hour; its volume will be augmented, and in place of 3000 to 3500 cubic metres it will have from 6000 to 8000 cubic metres while still preserving its "elastic" construction and not falling into the drawbacks of the rigid balloon. Airships of this volume are already in course of construction in Paris. If, under these conditions, one is content with a speed of 50 kilometres per hour, which is magnificent, one will be able to carry sufficient fuel for a continuous voyage of 50 or 60 hours, which means 25 to 30 hours for the outward and the same for the return journey.

But in 25 hours a balloon travelling at 50 kilometres per hour would cover 1250 kilometres. It can descend during the night when photography is impossible, setting out again the next day and even stopping *en route* if necessary. The perfection of the special balloon "fabrics," and the judicious use of the air-ballonnet, enables the balloon to remain in the air without any loss of gas, and the airship *Patrie*, which was perceived floating in the North Sea ten days after the storm tore it from its anchorage, shows the strength of the modern airship. *We are able to say that airships of from* 6000 *to* 8000 *cubic metres volume, and having from* 1000 *to* 1200 *kilometres "radius of action" are in course of construction.*

Consequently, in selecting convenient "centres" for establishing *aeronautical stations*, centres which will coincide with inhabited and accessible points to which one can easily convey the material and *personnel*, one will be able to cover a continent with a network of circles of 1000 to 1200 kilometres radius, each of which can be traversed by an airship carrying the explorers and their instruments in 20 or 25 hours. Fig. 81 shows how one can apply this system of exploration, which is so simple, so rapid, and so safe, to a prescribed region.

The centres indicated in this example are accessible. Two are in French, two in English, and one in Belgian territory. They are Timbuctoo, the shores of Lake Tchad; Leopoldville, for the Belgian Congo; Dongola and Lake Albert for the English stations. In describing about these centres circles of 1100 kilometres radius it is seen that the whole of Central Africa can be covered thereby, and the circles even "overlap." Therefore the exploring traveller in his dirigible can touch every part of the unknown country. Even the provision and the maintenance of the aeronautical stations for the immediate return journey may be dispensed with, as it can halt at a different centre to that from which it set out, which may be of great value in case of an unexpected storm. In this instance I have confined myself to Central Africa; by adding a sixth centre at Dakar the whole Mauretania would become "explorable."

Would airships which accomplished these expeditions be limited to securing "route photographs"? No, they would do much better, thanks to Colonel Laussedat's process, the principle of which I will explain in a few words.

In 1852, Colonel (then Captain of Engineers) Laussedat, impressed by the advantages that photography would afford in the compilation of maps, evolved a means of preparing topographical surveys by means of Daguerre's invention. For this purpose he employed not one photograph, but two, taken from the extremities of a long known so-called base. If one knows the angle of the lines of vision of the two apparatuses which have their optical axes turned towards the same point, from the two extremities of this base, one has a triangle, the two photographs taken simultaneously from which enable one to build up the actual structure. It is in fact "plane table" topographical surveying, with this difference, that instead of carrying out the graphic work upon the spot, one "carries the ground with him" and completes the work in the drawing office.

This excellent method is even capable of simplification. It suffices to place at the two extremities of a "base," the absolute length of which is known, two cameras, the objectives of which have their axes absolutely parallel, and to actuate their shutters at the same moment, which is a very simple matter with a battery and two electro-magnets. From these two photographs one can compile the map of the country up to the limits of the visible horizon by means of Dr. Pulfrich's remarkable instrument, the *stereocomparateur*, built by Zeiss, the eminent optician, one of which is retained in the museum of the Conservatoire des Arts et Métiers. A most renowned German Geodesian Professor, O. Hecker, of the Potsdam Geodesical Institute, has shown how one can make the most of this process.

And this simultaneous use of the parallel two cameras at the ends of a base of known length is possible on board a dirigible of the *Bayard-Clément* type, for example. The rigid and indeformable car, of which the length is 28 metres, will be the supposed base. The two cameras will be fitted permanently at its two extremities; their distance apart is at one and the same time definitely known and invariable. On board a dirigible of the largest dimensions the same two cameras could be installed about 50 metres apart, thus having a still more effective base. The photographic data necessary for the compilation of the map by the aid of the stereocomparateur in consequence will be absolutely correct. In this manner it is not merely a route survey obtained by photographing the subjacent ground that the aeronauts will bring back with them. These are the component parts for a "geographical map" as far as the limit of the visible horizon, a map correctly "fixed" both vertically and in distance for planimetry. Thus a few aerial expeditions made in the interior of one of the circles of which we have spoken will more than suffice to furnish the map of the entire country included therein.

But in order to render this endeavour practicable, the assistance of several nations is necessary. The map (Fig. 81) shows that for Central Africa that of France, England, and Belgium would suffice. The cost of an expedition of this nature would be infinitely less than that incidental to ordinary expeditions achieving the same results. The time would be perhaps one hundred times less, the precision would be superior, and the dangers would be diminished very appreciably.

So far as concerns the country adjoining the French North African possessions, no places would be missed where it would be possible to establish dirigible depôts.

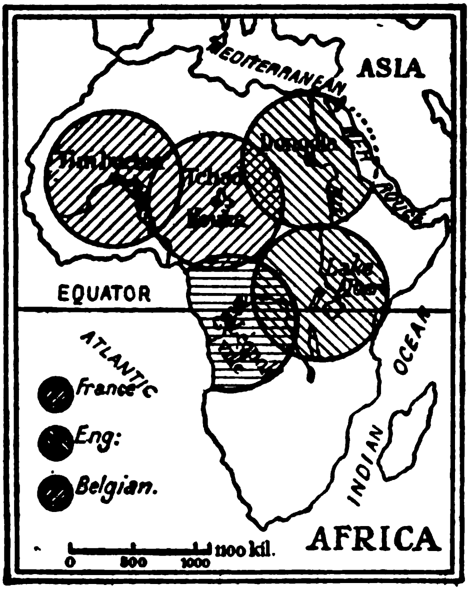


FIG. 81. The exploration of Central Africa by dirigible

Each circle represents an area actually accessible by an airship, and as all the circles overlap, the possibility of exploring the whole interior of the continent is evident

This system of working is not only applicable to Africa. The whole of the "Matto" of South America, the interior of Australia, as well as that of Asia, could be explored in this manner with material results through the co-operation of the interested Governments. Thus it would be possible to complete the "map of the earth," which, indeed, is the least that might be done, inasmuch as the photographic map of the heavens has been completed.

With regard to the North and South Polar Regions, undoubtedly it will be in this manner, and in this manner only, that we shall be able to learn their geography completely and quickly. We know how slowly explorations are able to proceed after the vessel is left—that is to say, in the same manner as one explores a new country. It is only by heroic effort that Polar explorers have made their perilous discoveries. Consequently it will be by dirigible that it will be possible to study the glacial regions, not only in the vain curiosity "to reach the Pole," but to learn scientifically the geography of the axial caps of our terrestrial globe. To have dreamed of this five years ago would have been madness, but in view of the achievements of the present-day airships, it is a feasible possibility. The distance from Spitzbergen, where one could establish a station, to the North Pole, is only 1300 kilometres (720 knots). Thus it is within the limits of dirigibles, when such have been perfected. Likewise, to solve the problem of the complete exploration of Greenland, a station at Uperniwick would be adequate; for the Arctic archipelago of North America a station on Hudson Bay would permit the aerial exploration of almost its entire area.

Let us point out that in the Polar regions, in the time of the solar summer, the day is continuous. Therefore, the balloon, would not be subjected to variation in its ascensional effort, and would have no need to descend, so that photography would be possible throughout the journey. Conditions for safety on the voyage among these deserts of ice, destitute of all resources, would only demand the use of several airships, following one another at some distance, and capable of extending mutual assistance in case of necessity. So far as the Antarctic is concerned, its exploration would be more difficult, owing to the extent of its surface, and, above all, the remoteness of its shores from civilisation. It would be necessary to establish special stations, and the "raids" that would have to be carried out by the airships would have to exceed 2000 or 2500 kilometres outward, as well as return. Undoubtedly, therefore, this will be the last part of the terrestrial globe that will be made known in regard to geographical details.

A clever Austrian officer, Captain Scheimpflug, has ventured into the realm of practice, and by the aid of an apparatus comprising several photographic cameras inclined towards the horizon, and grouped in the form of a star about a central vertical chamber, has secured some magnificent topographical maps on the scale of $\frac{1}{25000}$.

The aerial exploration of unknown continents is quite possible by means of dirigibles. I do not overlook the practical difficulties that stand in the way of realising the theoretical. It is essential to study climatic conditions, winds, and other factors incidental to particular tropical countries. But these difficulties can be overcome, and the aero-photographic exploration of the earth will be made, because it is *imperative* that such should be effected. We live in a hustling century, and our geographer will not tolerate the remissness in exploring the surface of our globe much longer.

So far as aeroplanes are concerned, I do not think that they will take part in geographical exploration so long as they are not provided with sustaining screws to permit them to remain stationary in the air. In their present form the impossibility of "stopping" prevents recourse to *photo-topography* therefrom. But they will be valuable auxiliaries in the sense that by rapid reconnaissances made at high speeds, they will be able to indicate the most interesting points of which it will be useful to have a detailed map, and upon which the dirigibles, after their indication, can be engaged.

There is one other application of dirigibles and aeroplanes. This sphere in which their use will be extended, is the necessity to learn, by careful study, the laws of atmospheric circulation in the highest and middle altitudes. As a matter of fact we scarcely know anything about the laws of this movement in the immediate neighbourhood of the earth, and but for the work of the Prince of Monaco upon the ocean, and those of M. Teisserenc de Bort by means of kites, France would be very much behind other nations in this respect.

If it is desired that aerial navigation should develop as it ought, the further exploration of the higher atmosphere is urgent. The increased knowledge that we can acquire in this way will be completed, if not exclusively furnished, by savants travelling in dirigibles and aeroplanes.

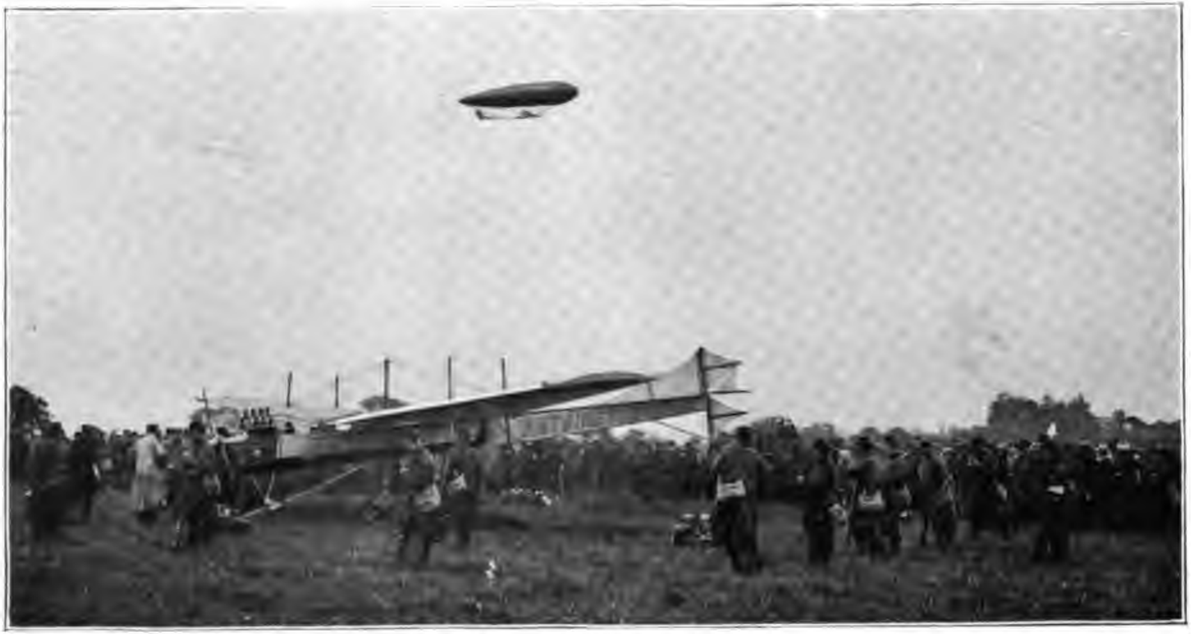
THE INDUSTRIAL MOVEMENT CREATED BY AERIAL NAVIGATION

Not one of the least benefits to locomotion through the air is the creation in a few months, as if by the wave of a magic wand, of a new industry, and the development of a considerable commercial movement the significance of which it is impossible to indicate.

In the first place the generous initiative of M. Henry Deutsch speedily found many imitators. There are several thousands of pounds offered as prizes for aviation in France alone. The Osiris legacy endowed French aeronautics by £4000, which the Académie des Sciences divided between the constructors, Blériot and Voisin. Through the generous and active initiative of M. Barthou, Minister of Public Works, whose brother, M. Léon Barthou, Vice-President of L'Aero Club de France and an audacious militant aeronaut, the public purse has voted a subvention of £4000 to aerial navigation. Let us add the prizes won already and the total becomes imposing. Yet that is only for "encouragement"! May we see a little of the amount effectively disbursed.

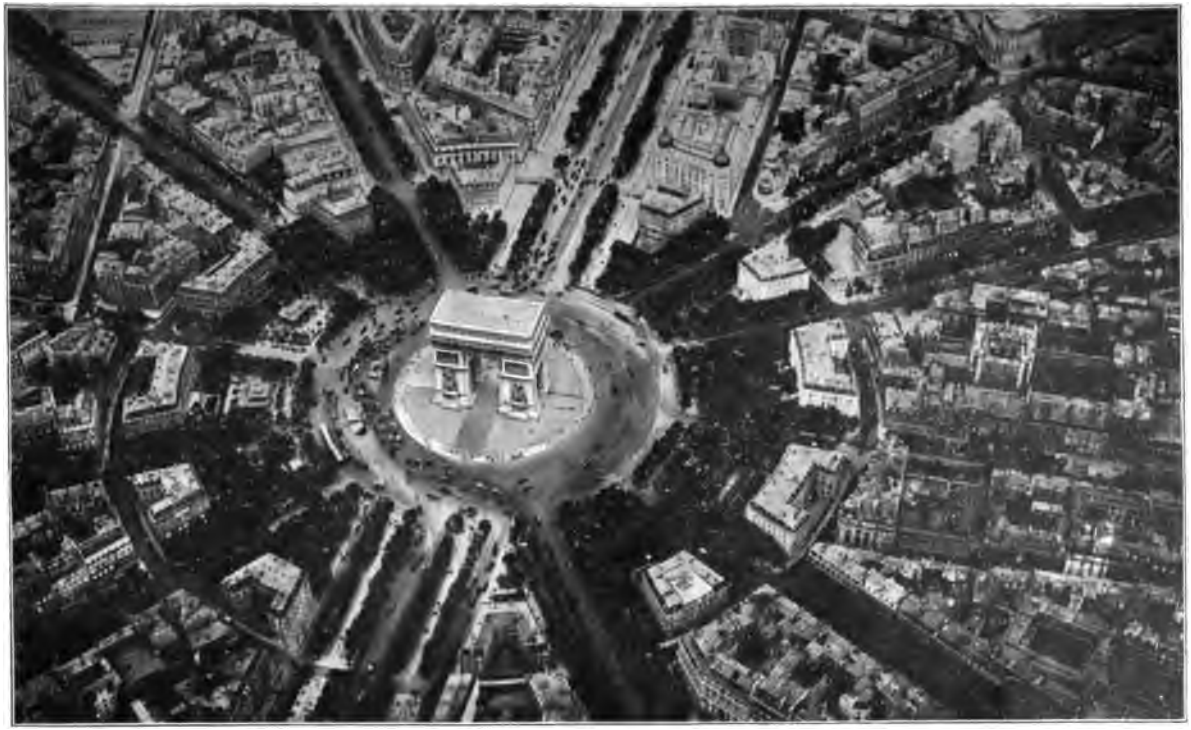
The French have at the present time several dirigibles—*Lebaudy*, *Nancy*, *Ville de Pau*, and *Ville de Paris*; the *Patrie* and the *République* were destroyed by accidents, but they have been replaced. There are also the *Liberté*, *Colonel Renard*, the *Lieutenant Chauré*, the *Captain Maréchal*, &c. In addition to these there are the *Bayard-Clément*, *Ville de Bordeaux*, *Zodiac*, *Belgique*, and *Russie* (built in French workshops), &c. That totals in all twenty important dirigibles built in four years. When one recollects that each costs on the average £12,000, that represents £240,000; but it is more than £240,000 if one takes into account the sheds and the money expended upon experiments. I do not take into consideration the numerous efforts of MM. Santos-Dumont and Comte de la Vaulx; of the attempts of MM. Malécot, Marçay, and others. By adding all together one obtains for this period of infancy and experiments an aggregate well over £600,000. This is an economic aspect of the question that one must not overlook, especially if one reflects that we are yet only in the early stages.

PLATE XLVII



THE “BAYARD-CLÉMENT NO. 2” MANŒUVRING ABOVE THE TROOPS AT THE FRENCH MANŒUVRES, WITH LATHAM PREPARING TO SET OUT ON HIS “ANTOINETTE” MONOPLANE

PLATE XLVIII



THE ARC DE TRIOMPHE DE L'ÉTOILE, AS SEEN FROM A HEIGHT OF 300 METRES

Reproduced by permission from "Paris vu en ballon," by A. Schœlcher and O. Decugis

And aeroplanes! It is by the hundred that one counts their construction now. The money expended upon an aviation apparatus is less than for an airship, that is certain, but it is precisely for this reason that a very large number of persons are participating therein, and it is by hundreds that it is necessary to enumerate them at this moment. If one admits that each, including the trials, represents an outlay of £800 (and we underrate the truth), we thus arrive, under this head, at many thousands of pounds. And here the development has been more rapid since the true experiments in aviation do not date back more than eighteen months. If one keeps account, moreover, of the money expended in fruitless experiments, in repairs, in expenses of all kinds, the balance-sheet of aerial navigation, both dirigibles and aeroplanes, shows a money movement of more than £2,000,000 during the past five years. That is excellent for a start.

And this is only in France. The whole world knows what enormous sums Germany has expended upon its military dirigibles: it exceeds 30,000,000 marks already. In England, the United States and Italy the movement is equally important. Aerial locomotion has given birth to an industry which appears likely to undergo a tremendous expansion. This industry creates a financial reflex because in France alone *numerous limited companies* have been established, representing a total capital of over £800,000. There are many others, also very important, abroad.

The Bourse has become entangled because, rightly or wrongly, speculations have already taken place in these new stocks. Moreover, owing to the incredibly rapid development of aerial navigation in its two forms, the civilised nations are preoccupied in a grave question—"international legislation" over the air. Upon the invitation of the French Government, which sent a detailed "note" to the different Powers, an "International Conference," as we have mentioned, was held at the Foreign Office in Paris on May 18, 1910. Aerial navigation figures consequently in the "European Concert." May the heavens never be the cause of strife.

WHAT REMAINS TO BE DONE?

Now what progress remains to be accomplished in order that aerial locomotion may maintain its excellent prospects for the future and in order that new conquests may justify the enthusiasm provoked by its glorious *début*?

In connection with dirigibles the first condition will be to obtain at once a speed of 60 kilometres per hour at least, so as to reduce to twelve or fifteen days per year the period of compulsory idleness. Then it will be necessary to increase their volume so as to increase the fuel-carrying facilities for participation on lengthy voyages; in a word their *radius of action* must be extended to 1000 or 1200 kilometres. I consider this indispensable. Also it will be available for armies and exploring expeditions, as we have mentioned.

But as the possibility of any accident to the motor must be prevented, it will be necessary to equip them with two independent engines and two propellers. Thereby the failure of one engine will not bring about disablement, or compel landing at some place where an accident may result. The balloon fabrics will be perfected still more, and will enable an airship to remain inflated for fifteen, twenty, or thirty days without taking another charge of gas. Certainly their construction will be improved, and one will learn the best means to avoid the cause of that "fermentation" of the rubber which is incorporated therein, and which may render the dirigible's envelope useless.

But one thing which will be requisite, in fact imperative, will be the construction of numerous sheds, landing stations and shelters. By this means, and by this means only, will the airship be able to render great service, not only in France, but in the colonies.

With regard to aviation apparatus much remains to be accomplished. At first it will be necessary to increase their security to a great extent, and to assure automatically their lateral equilibrium. We have seen that it is compulsory to increase their speed up to 150 or 200 kilometres per hour, velocities which we shall witness soon without a doubt. And at the same time it will be necessary to reduce the dangers of shocks at landing, dangers which will increase in proportion as the supporting surface will be diminished, because of the progressive increase of the speed of the aerial vehicle. It will be essential, more so than in balloons, to equip aeroplanes with two *independent* motors, each of which *alone* will suffice to assure sustentation and propulsion. In this manner only will it be possible to reduce to the minimum the risks of an aerial journey. The number of the devices for steering and control of the motor must be restrained to the minimum, so that the pilot has less to do. The facilities for accommodating passengers will have to be improved; it will be necessary to increase the radius of action, which now scarcely equals two or three hours' actual travelling at 80 kilometres per hour; special safety arrangements for cases where the aeroplane will have to descend upon a lake, a river, or the sea must be provided.

It may be said, generally speaking, that future progressive development is associated with the light explosion motor. It is not necessary to carry the latter to an extreme degree if durability is desired—that is to say, if embarkation upon long journeys is in view. Greater lightness may be abandoned, effort devoted towards a type similar to the excellent automobile engines which now are so perfect, so reliable and constant in operation. The recent exploits of Farman and Sommer flying with two and three passengers show that without abandoning the existing type of aeroplane it is possible to use heavier motors which, as a result, are stronger. Then I believe that aviation will record greater advance and become possible of making voyages of longer duration than hitherto. All serious accidents have been caused more or less by defects in the motors. It will be necessary particularly to improve carburation to the maximum degree, and to use petrol only of a known composition, exceedingly pure, and exempt from the least trace of water. It is equally vital, in order to secure the perfect running of an engine upon which their lives depend, for aviators to be extremely careful, even "fussy," like Count Lambert, for instance, and to filter their petrol themselves, not only in order to remove solid impurities, but to make sure there is not the smallest drop of water associated therewith.

And above and before all, the necessity of *launching* from level ground must be suppressed, since such may be unavailable, as, for instance, in a mountainous or forest country. If this obligation be persisted in, it will be a serious obstacle against the general application of aviation.

This is the goal to which the efforts of the investigators must be directed now. Flying machines must be able to "rise from the spot"; then they will have an immense future, and maybe we shall see *aeroplane-liners* ploughing the air with numerous passengers, whereas as yet we have only *aeroplane birds.* Possibly this development will be the first-fruits of that "aeronautical institute," for the foundation of which M. H. Deutsch offered a million francs to the Université de Paris, at the same time as M. Zaharoff gave £28,000 to found there a chair of aviation.

Now we arrive at the last lines of this volume. In writing it I have not been able to defend myself from a feeling of "human" pride, which I am sure the reader will share. As a matter of fact, is it not magnificent to think that man, so insignificant in Nature, so feeble in comparison with the forces of the universe, even so weak in reference to many of the living species, has been able, thanks to the inspiring effort of his brain, to tame the elements, to conquer them, and to become their master? That domain of the air, which seemed prohibited to him, he has penetrated, soon will govern it as he holds sway upon the earth, as he prevails upon and under the waters! Certainly the history of all his conquests is magnificent, but I think that undoubtedly the most fascinating is that which we have described. It is that by which man has at last freed himself from servitude upon terrestrial soil. He has broken the fetters that the laws of balanced weight imposed upon him by the speed of his machines, and now, henceforward free of all shackles, he will be able to dash without hindrance along the "Highway of the Air."

APPENDIX

Some of our readers perhaps will be desirous to learn in a more precise form the laws concerning the resistance of the air. For such we set forth in the following lines the essential formulæ for aeronautics and aviation.

(*A*) Resistance of the Air.—In the case of a surface of which the plane stands perpendicular to the direction of displacement, the resistance of the air is given by the relation

$$(1) \qquad R = \phi S V^2$$

in which S is the moving surface, expressed in *square metres*, V the velocity of displacement in *metres per second*, R the resistance in *kilogrammes* and ϕ a numerical *co-efficient* of which the value is only known with doubtful certainty (it varies according to the experimenters, between 0·08 and 0·16. Marine engineers for calculations concerning the propulsion of vessels by the wind take the number 0·125, the result of very ancient practice. Still the number 0·08 is the mean of more recent investigations by Le Dantec, Renard, Eiffel, Cailletet, and Colardeau).

The formula (1) corresponds to the case of Fig. 1.

(*B*) Resistance of the Air upon an Oblique Surface.—This is the case of the theoretical aeroplane, corresponding to Fig. 44, in which we designate by i the angle of the surface of the aeroplane with the direction of movement (angle of attack).

The thrust P moving against the oblique surface is expressed

$$(2) \qquad P = \phi S V^2 f(i)$$

$f(i)$ being an action of the angle i. This action is simple and must be of the form

$$f(i) = \lambda \sin i.$$

With regard to the value of λ, it is given by formulæ which differ according to the *savants* who have enunciated them. Here are the three which are the most used:

$$(3) \qquad \lambda = \frac{2}{1 + \sin^2 i} \qquad \text{(Colonel Duchemin)}$$

$$(4) \qquad \lambda = a - (a - 1) \sin^2 i \qquad \text{(Colonel Renard)}$$

in which a is a number between 1 and 2 and more in the neighbourhood of 2;

and lastly,

$$(5)\qquad \lambda = \frac{1 - m\,\mathrm{tg}\,i}{\frac{1}{(1+m)^2} + \frac{2m}{1+m}\,\mathrm{tg}\,i + 2\,\mathrm{tg}^2\,i}\qquad \text{(Soreau)}$$

formula in which m is the ratio, $\frac{1-h}{1+h}$ if one calls $2l$ *the spread* of the surface and $2h$ its dimension *in the direction of travel;* m consequently depends upon *the elongation* of the surface as well as λ.

At all events λ varies with the angle i. Let us call λ_0 its *mean* value and let us admit:

$$K = \phi\,\lambda_0$$

we have then for expression of the normal thrust bearing upon a flat plane, in the case of an angle of attack small enough to draw it without confounding the arc with its sine:

$$(6)\qquad P = KSV^2 i$$

the angle i was expressed in the function of the radius.

N.B.—Many authors often confound K and ϕ; it is important to avoid this confusion.

(*C*) Position of the CENTRE OF PRESSURE (or centre of thrust).—In reverting to Fig. 48 which graphically expresses as the result of experiment that the centre of thrust is drawn more to the front edge of the moving surface, one has to calculate the distance d between this centre and the centre of the diagram of the moving rectangle, by the formula conceived by the engineer M. Soreau.

$$(7)\qquad d = \frac{h}{2(1 + 2\,\mathrm{tg}\,i)}$$

$2h$ being the dimension of the rectangle in the direction of travel. Avanzini's formula, a little simpler, is the following:

$$(8]\qquad d = 0{\cdot}6\,h\,(1 - \sin i]$$

(*D*) M. BERGET'S SPEED FORMULA FOR DIRIGIBLE BALLOONS.—This formula is

$$(9)\qquad V = C\sqrt[3]{\frac{F}{S}}$$

in which V is the speed in *myriametres per hour*, F the engine effort in *horse-power*, S the surface of the maximum transversal section *in square metres*, and C the *co-efficient of advantage* of the airship (see Table on page 94).

(*E*) MEASURING THE SPEED OF AERIAL VEHICLES.—This operation, indispensable to aeronauts, and which will be to aviators also as soon as they can undertake voyages of some duration, is simply effected by means of the apparatus of the engineer Joanneton of which front and back views are shown in Plate XXI.

The apparatus is a copper quadrant one face of which carries an engraved "table" over which moves a rule. This rule indicates by the aid of ½-ratio gearing, the part of the angle at which turns a mirror with which it is solid and which projects from the back face. The aeronaut by the aid of a small telescope sees in this mirror the image of some arbitrarily chosen point upon the ground (a tree, steeple, building or what not), and follows this object *for one minute* while turning the mirror in such a manner that the image always rests in the field of the telescope. There is nothing more to do than look upon the "table," to see the intersection of the rule with the line of altitude shown by the barometer; the abscissa of the corresponding point indicated upon the horizontal edge of the quadrant gives the speed in kilometres per hour.

The apparatus, weighing about one kilogramme, owing to its weight hangs like a plumb-bob in the desired position: it is sufficient to hang it up by a cord and a ring to the suspension ring of the car.

GLOSSARY OF FRENCH AERONAUTICAL WORDS ANGLICISED BY THE TECHNICAL WORDS COMMITTEE OF THE AERONAUTICAL SOCIETY OF GREAT BRITAIN

PRELIMINARY REPORT

In view of the somewhat confused state of aeronautical terminology at present prevailing, a Technical Words Committee was appointed by the Aeronautical Society of Great Britain to draft a list of technical terms relating to aeronautics, and to define their meaning. The work of the Committee has proceeded along systematic lines, and has already resulted in the compilation of a glossary of the more general terms in use. It was decided, therefore, to issue this list forthwith, in the form of a Preliminary Report, as it covers fairly well the technical vocabulary involved in the ordinary course of aeronautical work. In due course, the Committee hope to issue a glossary covering the whole range of aeronautical terminology, but the work of selection and definition is necessarily slow when conscientiously undertaken. The Committee wish to draw attention to the fact that they have aimed at making their definitions of technical terms as simple and commonplace as possible. The definition of ordinary dictionary words that are sometimes used technically has, as far as possible, been avoided, in order to give that latitude of expression so much desired by all writers. In a few cases where certain words are used in contrary senses by different schools of writers—such as "aerodrome" and "airship"—the Committee have been forced to take arbitrary action; it is particularly in respect to the use of such words that the Committee hope to meet with support.

GENERAL TERMS

AERONAUTICS—The entire science of aerial navigation.

AEROSTATICS—The science of buoyancy in air by means of displacement; this is, therefore, the term to be applied to the science of aerostation.

AERODYNAMICS—The science relating to the effects produced by air in motion; this is, therefore, the term to be applied to the science of aviation.

AEROSTATION—That part of aerial navigation dealing with gas-borne or "lighter-than-air" machines.

AVIATION—That part of aerial navigation dealing with dynamically-raised or "heavier-than-air" machines.

Aeronaut—One who practises any branch of aerial navigation.

Aviator—One who practises aviation.

Pilot—An aeronaut qualified in aerial navigation.

Engineer—In charge of the power plant.

Helmsman—In charge of the steering.

Shed—The use of the term *shed* is recommended instead of *hangar*.

Harbour—A natural or artificial shelter.

Aerodrome—A ground set apart for flying purposes. The Committee do not recommend this term, but, in view of its somewhat general use, suggest that it should be employed only in the above sense. This suggestion is made without prejudice either to its derivation or to its application in another sense by authors such as Langley, Lanchester, and Graham Bell.

Dirigible—A power-driven balloon.

Airship—This term having occasionally been used to denote *aeroplane*, the Committee recommend its use only in the sense of *dirigible* in order to avoid confusion.

Helicopter—A flying-machine supported by one or more screw propellers rotating on vertical or approximately vertical shafts.

Ornithopter—A "flapping-wing" machine.

Flying-Machine—A generic term denoting machines used in aviation, as distinct from those employed in aerostation.

Aeroplane—A flying-machine provided with fixed planes supported dynamically by its movement through the air.

This term should *not* be used to denote the planes themselves, but should only apply to the whole machine.

Glider—An aeroplane unprovided with motive power.

Multiplane—An aeroplane with two or more main planes overlapping in plan form.

Biplane—An aeroplane with two superposed main planes overlapping in plan-form.

Monoplane—An aeroplane with a single main supporting plane, which may consist of a pair of wings outstretched on either side of a central body.

Tandem, Stepped—In some cases aeroplanes have more than one pair of wings, which may or may not be on the same level; such planes, if they do not overlap in plan-form, must necessarily be arranged in "tandem"; when not on the same level they are said to be "stepped."

For instance, "an aeroplane having three pairs of wings stepped in tandem."

Principal Dimensions

Area—This term is not a technical definition unless qualified by an adjective, as, for instance, "supporting" or "effective" area.

By area is meant, in the case of planes, the area of the plan-form, and is therefore measured in units of double surface. That is to say, both sides or surfaces are counted as one unit of area. Thus, by an area of 500 square feet is implied a surface of twice 500 square feet.

Surface—Attention is drawn to the distinction that exists between surface and area. *See* **Area.**

Weight—This being a general term, should only be used when qualified by an adjective, such as "net weight."

Net Weight—The weight of the complete machine *exclusive* of variable quantities, such as pilot, fuel, lubricants, &c.

Gross Weight—The weight of the complete machine *inclusive* of all variable quantities, *i.e.*, pilot, fuel, lubricants, &c.

Loading—The loading of a machine is its gross weight in pounds divided by the supporting area in square feet.

Principal Parts

Plane—Any element of area used for dynamic support or control.

In pure aerodynamics the term should only be used with a qualifying adjective such as "flat," "curved," or "cambered."

The prefix "aero" is restricted to the complete machine defined as an "aeroplane."

Wing—The present use of this term, by analogy with natural flight, denotes each of a pair of planes outstretched on either side of a central body, which wings, if continuous, would form a single plane.

Body—In flying-machines, the central longitudinal framework to which the planes and organs of control and propulsion are attached.

Carriage—That part of the machine beneath the body intended for its support on land or water.

Tail—In flying-machines, a plane or group of subsidiary planes, which may include both horizontal and vertical planes, behind the main planes.

Elevator—A movable plane or group of planes for directing and controlling the machine vertically.

Rudder—A plane or group of planes for guiding a machine to right or left.

Balancer—In aeroplanes, an organ—usually a plane—for maintaining lateral equilibrium.

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METRICAL MEASUREMENTS AND THEIR CUSTOMARY ENGLISH EQUIVALENTS

Length

1 millimetre = ·03937 inch
1 centimetre = 0·3937 „
1 metre = 39·37 inches
3·28 feet
1 kilometre = 0·62137 miles

Area

1 sq. millimetre = ·00155 sq. inch
1 „ centimetre = ·1550 „
1 „ metre = 10·764 sq. feet
1·196 „ yards

Volume

1 cubic millimetre = ·000061 cubic inch
1 „ centimetre = ·0610 „ „
1 „ metre = 35·314 „ feet
1·3079 „ yards

Capacity (liquid)

1 litre = 1·05668 quarts
·26417 gallons

Mass (avoirdupois)

1 gram = ·03527 ounces
1 kilogram = 2·20462 pounds

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